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Preface and Overview

As long as two years ago, a proposal was considered to prepare a special issue of this journal concerned with lamb marketing. For various reasons, it has taken this long to get this task accomplished. This issue represents considerable effort by a number of contributors. Over this two-year period, lamb prices have varied from a low of $0.40 per pound to a high of more than $1.40. Over this same period of time, sheep (ewe) numbers have declined more than 10 percent. This accelerated decline, following the loss of the incentive program, added to the period-of-year trends, indicates the precarious position of the U.S. sheep industry. Based on reports as of Jan. 1998, the rate of decline has been reduced, but not reversed. The purpose of this special issue, in part, is to explore issues relating to the current industry position and to suggest possible approaches to reverse the trend.[1] Other such attempts have been made in the past without evidence of success; however, this effort is a multi-disciplinary approach which specifically targets markets and marketing issues.

The first paper in this series (Bastain and Whipple)[2] documents the decline in numbers. Total lamb meat consumption has not declined at the same rate as indicated by the trends in flock inventory due to increased carcass weights (Field and Whipple) and imports (Meyer and Anderson). Although starting from a lower base, lamb consumption has not, in recent years, declined at a faster rate than beef consumption, and thus, may have suffered from some of the negative information regarding red meat in general.

Bastain and Whipple also point out that sheep production was initially located on the East Coast with the arrival of the early settlers, but that sheep production moved west with the opening of this region. The West (West Coast, Mountain States and Texas) accounted for two thirds of the sheep population by 1920. This picture remained relatively stable until around 1980, after which much of the decline in numbers has been in the West and, at times, at a somewhat greater rate of decline than in the Midwest and Eastern states. In more recent years, some states in the East have actually increased numbers.

The reasons for the build-up and later decline in the West may provide some clues to explain the overall problem. As mentioned by several authors in this report, one of these factors is, no doubt, predation and the costs of prevention are likely to be greater under the extensive conditions of the West. Continued efforts to reduce losses to predation must be a priority of the industry. This problem may well be more serious than stated or realized by current producers as those who suffered the greatest losses are no longer in the business. As a result of this, large areas of the country have abandoned sheep production as an agricultural enterprise. Labor costs such as herding, fencing and protection from predation are added complications. Others have referred to reduced availability, increased costs and restrictions on grazing of federal lands as a cause of industry downsizing. Other possible contributing factors may be distance to primary markets resulting in increased marketing costs and restrictions on the producers' ability to utilize alternative marketing channels such as niche, direct or cooperative marketing (Kazmierczak).

The accelerated decline in numbers in the West following the loss of the incentive program seems to confirm that wool income was more important to producers in this region and that the concurrent loss of incentive payment and the low wool prices have had a great impact.

Although predation and reduced wool income are major negative factors, problems in lamb marketing are of great concern. The paper by Williams

[1] In treating an issue of this nature, it is inevitable that some editorialization will occur, as has been the case with some of these comments.

[2] Where authors names are used reference is made to following papers in this issue.

and Davis indicates that marketing channels for lamb not only involve long distances, but a large number of intervening entities and that some of these (feeders, packers, breakers and wholesalers) may represent market segment concentration or points of constriction which have undue influence on price and producer options. Different profit centers may be leading the industry in opposing directions. These constrictions may also interfere with the transfer of value or preference signals between the two important endpoints, e.g., producers and consumers. For instance, several authors (Field and Whipple) have reported that consumers prefer leaner lamb and that they perceive lamb to be fat, but this signal has not been clearly relayed to the producer and feeder segments of the industry in a manner to bring about the needed changes. Concentration in slaughter and processing have clearly not resolved the problems of the industry, and perhaps have only accelerated them. Can these problems be overcome by decentralization and increased producer participation in slaughter and distribution? This appears to be happening to some extent in the East, but is more difficult for producers in the range states. A move toward branded products of consistent quality, as is being done with other species, may offer the potential to open additional market channels and increase total consumption.

It is well documented (Williams and Davis) that carcass weights have increased over the years and that this has resulted in an increased carcass fat (Field and Whipple). Increased slaughter and carcass weights generally work to the advantage of the feeder so long as the price received exceeds the cost of gain and if no significant price discount occurs from the increased weight. The former tends to occur with low grain prices and at least a reasonable fair price for slaughter lambs. This situation has contributed to the increase in the size of lambs being slaughtered which has also been accentuated by a much higher percent of lambs going through feedlots. Also, packer and breaker benefits from heavier weights (lower labor costs per pound of throughput) with the result that these points in the marketing channel may exercise undue influence on the industry. The economies of scale (both in terms of numbers processed and slaughter weight) are real, but this may be relatively small in respect to the markup in trade channels (Ward and also Purcell) and the negative influence this may have on the industry. For instance, Purcell has shown that in the period of 1978 to 1993 slaughter lamb prices decreased while retail prices of choice cuts, the point at which the markup occurs, more than doubled. This spread may represent inefficiencies or disproportionate profit-taking. Thus, lamb becomes less competitive with other meat products, and the industry is becoming dependent on the decreasing portion of the population which will search out and purchase lamb at any price (speciality demand).

At this point, it is not clearly established what the consumer desires with respect to carcass weight (cut size). A preference almost certainly exists for larger chops which favors larger carcasses. However, imported lamb (from Australia and New Zealand) is apparently finding a ready outlet, although these carcasses are considerably smaller than domestic lamb (Meyer and Anderson). Is it possible that some of the incentive for larger carcasses are, in part, to balance out the supplies of smaller imported carcasses or cuts? If this (larger carcasses) constitutes a form of protection for the U.S. industry, this advantage will likely be reduced in the future as the exporting countries gear up to produce larger carcasses. It seems likely that the U.S. sheep industry should look with favor on increased carcass size, but this increase should preferably be obtained through management and the selection and use of larger sire breeds or lines. Increased slaughter weight brought about through increased ewe size may (will) carry penalties in the producer segment which are not clearly understood. A challenge to the industry in the future is to produce more lambs to keep a supply in trade channels and at the same time to provide an increased number of replacement females. This will require greater emphasis on increasing the size of the lamb crop weaned, and at least a part of this must be through genetics of the ewe flock. The production of heavier slaughter weights or larger carcasses should be obtained without an increase in the amount of fat. This may require the adoption of new technology for use in selection and marketing (Berg, Neary and Forrest).

Price markup, particularly at the retail level, is greater for lamb than for competing products and is a major problem in expanding lamb consumption. This is understandable, to some extent, due to the small volume in trade channels or the small part that lamb contributes to the total retail meat trade. Many retailers may carry lamb only to cater to a few customers who they view as being less influenced by price. Altering this will not be easy. The availability of some advertising or merchandising funds will likely be necessary.

A clear challenge to the sheep industry is to reverse the decline in numbers. Jones and Shroeder report that, in the short term, breeding sheep numbers show little or no correlation with prices of lamb or wool, but that in the long term (15 to 30 years) there was a small but positive relationship to lamb and wool prices and a negative response to feed and labor costs. The response to lamb price was greater than for wool. Prices seldom remain favorable for long periods of time, and producer confidence in the future may well be more important than price at any given point in time. Current lamb prices, when adjusted for inflation, are not more favorable than at certain periods in the past. In the model discussed by Jones and Schroeder, the revenue associated with lamb and wool prices has only a modest relationship to changes in ewe numbers. This suggests other factors are also important. Those previously mentioned include predation (or fear, concern or worry about predation) and labor, but in this modeling effort grazing fees on federal lands, feed costs (grain) as well as changes in calf prices are factors affecting trends in numbers. There is a widespread belief that where sheep must compete with cattle for the same resources, the actual or perceived future profitability of sheep must be higher than for cattle to overcome the image problem and concerns about predation and labor.

Although individual producers may benefit from price increases brought about as a result of reduced numbers, these situations are usually temporary as imports tend to take up the slack as soon as this reaction can occur. This situation tends to give rise to a "step down" in numbers as suggested by time trends. For the industry as a whole to thrive or perhaps even survive, some increased demand must occur. This may require that we (1) offer an improved product, (2) reach potential consumers that are not presently being served at a price they consider reasonable, and (3) increase per capita consumption by traditional consumers of lamb.

In terms of offering a better product, one requirement is to consistently present a product without excessive fat (Berg, Neary and Forrest). The knowledge to do this is available, but the price incentive is not always present or adequate. There is also a need to get a better handle through research on the reasons that some potential consumers do not eat lamb (Jamora and Rhee). Some information is available to characterize the unique properties of lamb meat, but technology is available to do a much better job of responding to this need. Lamb is the most identifiable red meat product which surely indicates that it is different. Although not addressed in this series of papers, some people suggest that an unfavorable experience by U.S. servicemen who were served Australian mutton during World War II has been a major factor in the decline in lamb consumption since that period of time correlates very closely with the serious decline in sheep numbers. Not only did these individuals not consume lamb, as heads of households for the last 50 years, they have had an impact on an entire generation. This age group is now phasing out of the population, and, thus, there is an opportunity to impact a new generation of potential lamb consumers. It has been shown that as much as 24 percent of the U.S. population will readily consume lamb, and another 50 percent have tried lamb. With a population of 260 million and growing, there is certainly a great potential for even larger quantities of lamb to be consumed in this country if this market can be accessed. Producers have a vested interest in the future of the sheep industry and must become more involved in marketing their products. Some of the issues involved are discussed in more detail in the paper by Purcell which occurs last in this series.

In summary, the industry must deal effectively with predation, must produce a consumer acceptable product, must work to explain and overcome the negative image of lamb, and must develop procedures to access the larger market for lamb that almost certainly exists in this country. This may (will) require opening additional or alternative marketing channels. The growth of ethnic markets throughout the country offers a potential entree to accomplish this need.

Prepared by Maurice Shelton and Paul Rodgers

An Historical Overview of Lamb Marketing in the United States and Considerations for the Future

Chris Bastian[1] and Glen Whipple[2]

Summary

The lamb marketing system has changed dramatically over the years. This article examines the changes in that system in order to provide an overview from which to draw reference for the rest of this Special Issue focusing on lamb marketing. Sheep production has changed from an emphasis of being produced primarily for wool in the 1800s to meat being of primary importance. Production moved from the East to the West as inexpensive range became available in the West during the later 1800s. Production in the 20th century peaked in 1942 and has declined to a level reminiscent of the early 1800s. As production has declined, lamb feeding and lamb slaughter has declined and become more concentrated. Historically, concentration in the lamb packing industry has been relatively high compared to other species in the meat industry, but in recent years it has become even more so. The impacts of increased concentration are not well understood. Perhaps the most disturbing implication of this increased concentration is the indication of deteriorating market infrastructure. Consumer demand for lamb has trended downward since 1945. This declining demand has likely provided much of the impetus for the decline in production. The lamb industry must address the issue of declining demand if it is to stabilize or grow in the future. Overall, it would seem that increased cooperative, promotional and marketing efforts by individual producers will be important for the long term survival of the industry.

Key words: demand, market infrastructure, concentration, marketing system.

Introduction

The evolution of a commodity into a consumer-ready product once it leaves the farm or ranch is becoming an increasingly important and controversial topic. The sheep industry is not unique in its concerns about marketing trends for its lamb and wool products. The marketing process for lamb has changed over the years, and it will continue to change. Howard Wyman pointed to the dynamic nature of lamb marketing and the need for change when he stated, "The old method of pushing carcasses out the back door hoping there is a market for them – will go by the wayside" (Wyman, 1984). It is hoped that this historical perspective on lamb marketing can provide a basis for understanding the industry today as well as providing possible paths for the future.

McCoy and Sarhan (1988) define marketing as the area of economics concerned with the exchange and valuation of goods and services. Others define marketing as what happens to a product after it is produced and until it is received by the consumer (Shepherd and Futrell, 1982; Lesser, 1993). Regardless of whose definition is correct, both imply a broad system including or closely linked to production. This article will take a historical look at the lamb marketing system. The lamb marketing system's segments include production, lamb feeding, slaughter, wholesale fabrication and distribution, retail operations and lamb consumers (Texas Agricultural Marketing Research Center [TAMRC], 1991).

Production

The number of U.S. sheep has fallen to a level reminiscent of the very early 1800s. Census figures indicate an estimated sheep population of seven

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million head in the year 1810 with New England and New York comprising the sheep producing center of the nation (Ensminger, 1964). By 1840, sheep numbers had increased to nineteen million head, and Missouri was the only state west of the Mississippi River having sheep in significant numbers. Ten years later, the densest sheep population was centered in the Ohio Valley and Great Lakes region. The opening up of western range led to an almost immediate and marked shift of sheep population from East to West. Sheep numbers peaked to a historic level of over 56 million head in 1884. Ensminger (1964) points out that during that time period, sheep were maintained primarily for wool production and production for market lambs was insignificant at that time.

Sheep and lamb production has experienced some changes since the 1920s. During the years of 1924 through the early 1930s, stock sheep numbers trended upward from slightly less than 33 million head to nearly 48 million head (Figure 1). Stock sheep numbers then declined and remained near 45 million head until 1939. Inventories increased until a peak for this century of slightly over 49 million head in 1942. After 1942, stock sheep numbers dropped rapidly during the remainder of that decade; then remained relatively stable at 26 to around 28 million head through the 1950s and the early 1960s. Stock sheep numbers then trended downward again from over 27 million head in 1962 to slightly less than 11 million head in 1979. Numbers stabilized around the 10 million head mark until the middle 1980s, before declining to current levels. In 1995, stock sheep numbers were estimated at 6.44 million head according to the U.S. Department of Agriculture (USDA; 1996). As expected lamb numbers followed much the same pattern peaking in the 1940s at around 32 million head and declining to 5.66 million head by 1995 (Figure 1).

The overall decline in sheep production has been attributed to decreased demand for lamb and wool, management and herder problems, predator problems and decreased grazing permits (Shapouri, 1991; McCoy and Sarhan, 1988; Engelman et al., 1973). The decline in sheep numbers has been slightly offset by increased lambing rates and heavier slaughter weights. The average lambing rate in 1940 of 87.05% had risen to nearly 108% in 1989 (Shapouri, 1991). Shapouri (1991) also indicated a trend toward increased average live weight of animals slaughtered from 86 pounds in 1940 to 124 pounds by 1989.

The long decline in sheep inventory masks the cyclical trends in the industry. Cycles are movements in livestock inventories and prices which last for more than one year and follow a pattern that repeats itself (McCoy and Sarhan, 1988). Typically, inventory cycles and price cycles for agricultural commodities are inverse of each other. Thus, when inventory is high prices tend to be low and vice versa. Turning points in price cycles tend to lag behind turning points in inventory cycles, however. McCoy and Sarhan (1988) indicate that prior to World

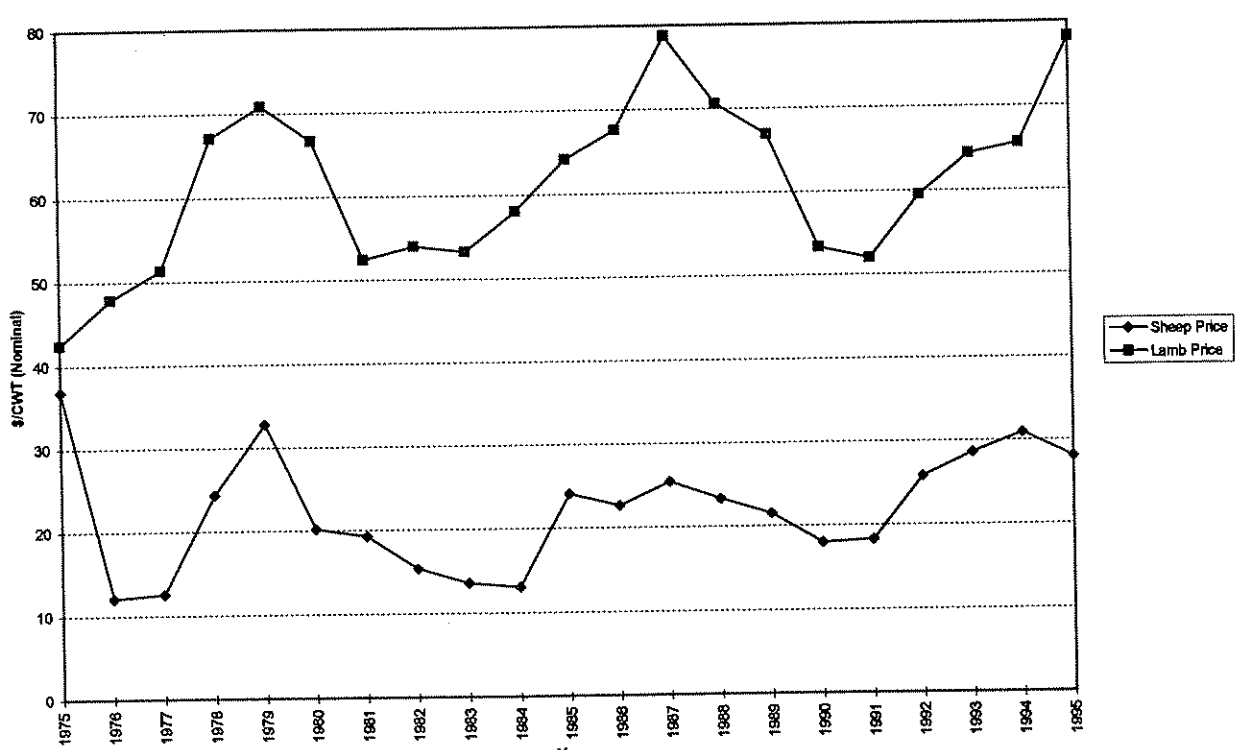
Figure 1. Stock sheep and lambs (1924 through 1995).

War II, there were seven discernible cycles in the sheep industry with an average length of about 10 years. McCoy and Sarhan (1988) stated the downward trend after World War II virtually obliterated discernible cycles. VanTassell and Whipple (1994) used harmonic regression techniques to study cycles in sheep inventory and prices during the period of 1924 through 1993. They found that the cycle length declined over time from 13 to 10 years. Their results indicated that price cycles varied between 8 and 13 years during the same time period. Figure 2 graphs nominal prices for sheep and lambs between 1975 and 1995. Graphically, the price cycle appears to be approximately eight years in length from peak to peak which tends to confirm the results of VanTassell and Whipple (1994).

The regional location of sheep and lamb production also has changed since 1920. Sheep are found in most of the U.S. except for some states in the Southeast where environmental conditions limit their production (Shapouri, 1991). The majority of U.S. sheep have been produced in the Mountain states and West Coast states since 1920. Stock sheep and lambs in the Mountain and West Coast states accounted for 57.4% of all U.S. stock sheep and lambs as of January 1, 1920 (Table 1). Those same states had 47.7% of the stock sheep and lambs in 1990 (Table 1). In 1920, the West North Central and West South Central States were less important than the states east of the Mississippi River, accounting for around 21% of the stock sheep and lambs inventory (Engelman et al., 1973). By 1940, the percentage of stock sheep and lambs in those states had risen above 35% and remained stable for the rest of the period (Table 1). Finally, the East South Central and East North Central states have experienced a gradual decline in importance between 1920 and 1990 (Table 1). The increased importance of the Midwestern states (West North Central, West South Central) may be related to the increased importance of grain feeding and availability of feed supplies in those regions.

Generally, lamb producers have several options at weaning. They can: 1) sell their lambs as feeders to a feedlot buyer; 2) retain ownership of the lambs through contract feeding; or 3) sell heavy lambs directly for slaughter after weaning (Botkin et al., 1988; Engelman et al., 1973). Southern states, or states with more favorable production conditions, tend to sell more slaughter lambs at weaning. These are sometimes called "milk-fat lambs." Engelman et al. (1973) reported that Oregon, Washington, California, Texas and the combined region of Missouri/Arkansas/Louisiana all had 40 to 55% of their total lamb slaughter supplied from milk-fat lambs during July of 1969 through June of 1970. In the Western states, less than 16% of total

Figure 2. Sheep and lamb prices (1975 through 1995).[a]



slaughter was represented by milk-fat lambs for the same 12-month period. States with harsher climates such as the Western States tend to sell more feeder lambs at weaning. Botkin et al. (1988) estimated that 61% of the lambs in the West are sold as feeders due to a shorter growing season or early depletion of the feed supply which reduces the weight of lambs that can be sold to packers. Botkin et al. (1988) also reported that the majority of feeder lambs produced in confinement situations common to the Midwest are early-weaned, confinement-fed and marketed as slaughter animals. This supports the notion that the rise in importance of the Midwestern region in sheep production is related to the availability of feed.

Marketing Methods Used By Lamb Producers

Just as the numbers and locations of feeder lamb production has changed over time, so have the marketing methods used by producers. Many of these changes have been brought about due to changes in technology. There are a number of marketing alternatives available to producers for the sale of both feeder and slaughter lambs. These alternatives include direct negotiation between producer and feeder or packer, sale through buyers and dealers to feedlots or packers, terminal markets, auction sales, special sales, electronic and video sales and niche marketing directly to consumers (Botkin et al., 1988).

Ensminger (1964) reports that up through World War I, the majority of slaughter livestock were sold through terminal public markets by farmers and local buyers shipping to them. Terminal markets are livestock trading centers where livestock are assembled at a single geographic location in large numbers to be sold on a private treaty basis (McCoy and Sarhan, 1988; Ensminger, 1964). The percentage of federally-inspected slaughtered sheep and lambs coming from terminal markets declined from about 86% in 1923 to 51% in 1951 (Ensminger, 1964). The volume of sheep and lambs sold in terminal markets equalled 34.7%, auctions accounted for 14.1% and direct sales to packers, feeders, agents for packers or feeders or to other farmers accounted for 48% of the sheep and lambs sold by producers in 1955 (USDA, 1958). By 1987, the percentages of total sheep and lambs sold through these avenues had changed to 5.5% for terminal markets, 13.1% for auction markets and 81.4% through nonpublic methods (Stillman et al., 1990). Botkin et al. (1988) report that direct negotiation between feeder lamb producer and feedlot management is the most common method used to market relatively large numbers of feeder lambs. They also report direct sales from producers or feeders to the packer through forward contracting is the most common method of marketing slaughter lambs.

The decline of terminal markets along with the growth in auctions was largely due to the decentralization of markets. In the late 1800s most sheep sold for slaughter were transported by rail. The first terminal market which operated into the 20th century was established in Chicago, IL, with railroad access, in 1865 (Ensminger, 1964). Most of the larger terminal markets operating in this century were established in the latter half of the 19th century. They were a logical outgrowth of the pattern of railroad transportation and the location of packing plants at rail terminal points (McCoy and Sarhan, 1988). Technological developments in transportation and communication, along with the

Table 1. Distribution of stock sheep and lambs on farms (January 1, selected years, 1920 through 1990).[a]

	Year, %							
Region[b]	1920	1930	1940	1950	1960	1970	1980	1990
West Coast	14.4	14.1	11.0	9.7	9.7	10.1	13.8	12.5
Mountain	43.0	40.8	35.1	34.4	32.4	37.9	37.9	35.2
West North Central	10.6	11.4	15.2	14.0	22.1	17.7	16.4	18.6
West South Central	10.2	14.8	21.8	25.7	19.2	21.1	20.4	20.8
East North Central	11.6	10.2	9.6	8.4	9.4	8.3	5.7	5.5
East South Central	3.5	3.1	3.4	3.7	3.1	1.0	0.3	0.5
Northeast	3.5	2.5	1.6	1.5	1.7	1.7	1.9	3.0
Southeast	3.2	3.1	2.3	2.6	2.4	2.3	3.7	4.0
All regions	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Data for this table comes from Shapouri (1991).
[b] West Coast: CA, OR, WA.
Mountain: AZ, CO, ID, MT, NV, NM, UT, WY.
West North Central: IO, KS, MO, MN, ND, SD.
West South Central: AR, LA, OK, TX.
East North Central: IL, OH, MI, WI, ID.
East South Central: AL, KY, MS, TN.
Northeast: CT, ME, MA, NH, NJ, NY, PA, RI, VT.
Southeast: DE, FL, GA, MD, NC, SC, VA, WV.

decentralization of packing plants, adversely affected the use of terminal markets (McCoy and Sarhan, 1988).

It was not until the 1920s and 1930s that auction markets for livestock became prevalent. Again, the decentralization of the packing industry coupled with the technologically enhanced ability to transport livestock lots of various sizes quickly and economically made local auctions an attractive alternative for producers. Expansion of auction markets continued through the 1940s and gradually began tapering off in the early 1950s (McCoy and Sarhan, 1988).

One advantage of auctions over terminal markets came from a more efficient price discovery process. Transactions at terminal markets were generally private treaty arrangements. Auctions determine prices through open outcry. This type of price discovery can lead to a more efficient price determination (McCoy and Sarhan, 1988). Auction selling has become the norm at terminal markets.

Other avenues which use public bidding to establish prices have developed using improved technology. These newer methods include teleauctions, computerized auctions and video auctions (McCoy and Sarhan, 1988; Botkin et al., 1988). Teleauctions use the telephone as a means to communicate among bidders and sellers. Holder (1979) found that a cooperatively-owned teleauction started in 1971 effectively increased the number of buyers and competition for slaughter lambs in Virginia. Prices received by participating producers increased $1.90 per hundredweight (approximately 7%) over previous prices received before using this method. Computerized auctions use computers as a means of communication among buyers and sellers. A drawback of both teleauctions and computerized auctions is the lack of visual appraisal of livestock (McCoy and Sarhan, 1988). The video auction addresses this issue by taping livestock and allowing market participants to view the tape during the bidding process. None of these methods has increased markedly in their sales volume for sheep and lambs since their inception. Even so, they provide additional marketing alternatives for lamb producers (Botkin et al., 1988).

Lamb Feeding

Prior to 1900, sheep feeding consisted of fattening the older animals – ewes and wethers – chiefly on inexpensive flour mill by-products and prairie hay (Ensminger, 1964). As a result the sheep feeding industry was located near the flour-milling centers of St. Paul-Minneapolis, MN, and Chicago, IL. These operations proved very lucrative early on, but competition for feeder sheep increased causing prices to rise. Simultaneously, the flour mill by-products were found useful in feeding other types of livestock, thereby increasing feed costs (Ensminger, 1964). During the interim, Corn Belt farmers became interested in fattening sheep and the market demand shifted to young lambs. These factors stimulated the steady decline of the sheep feed yards located near the large flour mills, beginning around 1900 (Ensminger, 1964).

Lamb feeding became dispersed during the early to mid-1900s in those areas where feed was abundant. However, as sheep production declined and packers became more concentrated, lamb feeding also declined and became more concentrated in some states (American Sheep Industry [ASI], 1996; Scott, 1986). Table 2 indicates an overall trend of less lambs on feed between 1966 and 1993. Most states have experienced declines in lamb feeding as numbers of sheep have declined. However, lamb feeding has increased in California and remained relatively stable for Wyoming. The relative importance of Texas as a sheep feeding state has also increased since the 1960s. Lamb feeding has become more concentrated overall. The top four lamb feeding states accounted for around 43% of the total lambs on feed for 1966 and 1972 (Table 2). By 1993, the top four states (Colorado, California, Texas, Wyoming) accounted for nearly 52% of the total lambs on feed. Moreover, the top ten states show an increase from 68% of the total

Table 2. Major lamb feeding states (1966 through 1993).

Year	State	U.S. lambs on feed, %
1966:[a]	CO	16.8
	IA	10.5
	NE	9.0
	SD	6.8
	CA	5.7
	KS	5.4
	MN	4.6
	WY	3.7
	TX	3.6
	OR	2.0
U.S. total *(1,000 head)*		3,278
1972:[b]	CO	17.3
	TX	13.8
	IA	6.2
	WY	6.0
	SD	5.2
	KS	4.0
	MN	3.8
	CA	3.5
	OR	3.4
	AZ	3.1
U.S. total *(1,000 head)*		2,894
1986:[a]	CO	16.1
	CA	13.7
	TX	10.1
	OR	7.0
	WY	6.7
	NM	5.7
	SD	5.4
	IA	4.7
	NE	4.4
	MN	4.2
U.S. total *(1,000 head)*		1,492
1993:[b]	CO	16.6
	CA	16.1
	TX	9.5
	WY	9.2
	OR	5.0
	SD	4.8
	KS	4.6
	IA	4.5
	AZ	3.7
	MN	3.2
U.S. total *(1,000 head)*		1,894

[a] As reported by Scott (1986).
[b] As reported by ASI (1996).

lambs on feed in 1966 to nearly 78% for both 1986 and 1993 (Table 2).

The level of packer feeding also changed over time. Engelman et al. (1973) reports that meat packers began feeding cattle and lambs during World War II due to procurement problems. Data was not kept on livestock feeding by packers until 1954. The average percentage of packer fed lambs compared to total number of lambs slaughtered was 7.6% during the period between 1955 to 1969.

During the 1970s packer feeding of lambs remained relatively stable at about 15% of the total sheep and lamb slaughter according to data collected by Packers and Stockyards Administration (P&SA; ASI, 1996). The percentage of total slaughter coming from packer fed lambs reached a low of 4.2% in 1981 and peaked at about 30% of total slaughter in 1988. Since that time, packer feeding seems to have stabilized at around 28% of total slaughter (ASI, 1996). Packer feeding of lambs was located primarily in Colorado, California, Texas, Washington, Kansas and Iowa in 1988. These changes are not surprising given the increased concentration of feeding and packing operations and the decline in sheep numbers. As supplies become tighter, packers would be expected to try and secure more supplies for their plants.

Lamb Slaughtering

Lamb slaughter volume has declined along with the total number of sheep and lambs. Number of lambs slaughtered dropped sharply in the 1970s to a low in 1978 (ASI, 1996). Since then lamb slaughter has followed the total sheep inventory and lamb production cycle. Slaughter in 1992 was nearly 5.5 million head (ASI, 1996).

The distribution of commercial sheep and lamb slaughter also changed over time (Tables 3 and 4). Engelman et al. (1973) reported the distribution of commercial sheep and lamb slaughter by region during the period of 1944 through 1970 (Table 3). They concluded that sheep and lamb slaughter had been moving westward since 1944 (the first year commercial slaughter was reported by state). The Mountain states showed substantial growth in slaughter numbers over that time period. They accounted for only 4% of U.S. slaughter in 1944, but by 1970 had increased their share to 23%. The West South Central states (primarily Texas) more than doubled sheep and lamb slaughter, from 6% in 1944 to almost 13% in 1970. The West North Central states went from 40% of the sheep and lambs slaughtered in 1944 to 23% in 1970 (Table 3). The states east of the Mississippi River also experienced a decline, from 37% of the sheep and lamb slaughter in 1944 to about 23% in 1970 (Table 3). Engelman et al. (1973) concluded that the westward trend in sheep and lamb slaughter was part of the general trend in the slaughter of all livestock. Improved carcass storage and transportation technologies stimulated a shift in slaughter from consumption areas to production areas (McCoy and Sarhan, 1988; Engelman et al., 1973).

Table 3. Distribution of commercial sheep and lamb slaughter (by region, selected years, 1944 through 1970).[a]

	Year, %				
Region[b]	**1944**	**1950**	**1960**	**1965**	**1970**
West Coast	13.3	15.5	17.9	18.4	18.6
Mountain	3.7	6.8	12.3	19.2	23.1
West North Central	39.7	36.8	32.1	28.0	22.7
West South Central	6.1	5.3	8.1	9.5	12.9
East North Central	18.5	13.5	11.1	10.7	10.9
East South Central	1.2	1.6	1.8	2.2	1.9
Northeast	16.6	19.8	15.9	11.4	9.4
Southeast	0.9	0.7	0.8	0.6	0.5
All regions	100.0	100.0	100.0	100.0	100.0

[a] Data for this table comes from Engelman et al. (1973).

[b] West Coast: CA, OR, WA.
Mountain: AZ, CO, ID, MT, NV, NM, UT, WY.
West North Central: IO, KS, MO, MN, ND, SD.
West South Central: AR, LA, OK, TX.
East North Central: IL, OH, MI, WI, ID.
East South Central: AL, KY, MS, TN.
Northeast: CT, ME, MA, NH, NJ, NY, PA, RI, VT.
Southeast: DE, FL, GA, MD, NC, SC, VA, WV.

At the state level, the location of slaughtering changed between 1972 to 1990 (Table 4). Colorado, with a growing share, continues to top total volume slaughtered in the U.S. The top three states accounted for nearly 50% of total slaughter in 1972, 1985 and 1990 (Table 4). The top ten states' share varied between 79 and 91% during those same years (Table 4). Slaughter data by state are no longer published, but the Livestock Marketing Information Center (LMIC; 1997) estimated the top ten lamb slaughter states for 1996 to be (in alphabetical order): California, Colorado, Illinois, Indiana, Iowa, Michigan, New Jersey, Pennsylvania, South Dakota and Texas. Slaughter volume for those states in 1996 was estimated to be nearly 95% of the slightly over 4 million head slaughtered.

The number of lamb slaughtering plants has declined. Fewer lambs to slaughter and technological advances which require slaughter plants to be larger in order to be cost efficient have been the driving force behind declining plant numbers. Engelman et al. (1973) reported that were 31 U.S. plants slaughtering more than 100,000 head of sheep and lambs in 1969. The total number of lamb slaughtering plants reporting to P&SA declined from 206 in 1974 to 138 in 1990 (ASI, 1996). Of those 138 plants, 95 plants slaughtered less than 10,000 head each. In 1990, six of those 138 plants slaughtered an average of 577,833 lambs which accounted for 74.3% of total lamb slaughter. Four lamb packers have closed plants since 1990 (U.S. International Trade Commission [ITC], 1995). The most recent shutdown was a Monfort plant located in San Angelo, TX, in 1995 (U.S. ITC, 1995). Engelman et al. (1973) concludes that the general pattern of fewer plants for sheep and lambs as compared to other species was related to the limited amount of lamb and mutton meat produced compared to beef and pork.

Given the decline in sheep production and lamb slaughter, it is not surprising that the lamb packing industry has become more concentrated. The lamb slaughter industry, however, has always been relatively concentrated. Engelman et al. (1973) reports that the four largest sheep slaughterers accounted for almost 62% of the sheep and lambs slaughtered in 1920. The market share for the top four firms increased during the 1930s and 1940s and then declined in the early 1960s with packer decentralization. The four-firm concentration ratio increased from approximately 55% in 1972 to approximately 70% in 1990 (ASI, 1996). Due to mergers and consolidations in 1987, the four-firm concentration ratio peaked in 1988 at 76.5% (ASI, 1996). Azzam and Anderson (1996) reported a four-firm concentration ratio of 73% for lamb slaughtering in 1994. Engelman et al. (1973) concluded that the higher concentration ratios for sheep and lamb slaughtering compared to other species reflected the smaller number of packing plants slaughtering sheep relative to cattle and hogs.

Increased concentration in the sheep packing industry has caused concern about possible impacts on price for lamb (TAMRC, 1991; Menkhaus et al., 1989; McCoy and Sarhan, 1988). Menkhaus et al. (1989) conducted research to ascertain the impact of concentration in the lamb slaughtering industry on lamb prices. The authors conclude tentatively that there is limited evidence to suggest that plants purchasing lambs in a concentrated buyer environment offer lower prices than those purchasing in a less concentrated environment. They go on to speculate that efficiency of one or a few buyers may be more important than the competitive atmosphere (i.e., higher concentration may lead to increased efficiencies and perhaps higher, not lower, prices received by producers for lamb). While the pricing issue is important, perhaps the most disconcerting aspect of the increasing concentration in lamb packing is its indication of continual decline in the market infrastructure for the sheep industry.

Market infrastructure can be defined as the foundation or internal support system necessary for the market to function efficiently. For example, access to transportation, roads, storage facilities, information transfer, legal institutions, grading systems and access to market outlets are necessary for a market to function. As consumers purchase less lamb, distributors become less willing to supply lamb. This in turn means less packers are needed to supply the lamb to distributors, and the packers in turn require less volume. Market outlets for feeders become less and the demand for feeder lambs weakens. Market information becomes less available as the market becomes thin and more vertically coordinated. Thus, the whole market deteriorates as the foundation or infrastructure for that system declines. The drop in packer numbers and other firms dealing in the lamb marketing system points to an overall deterioration of the infrastructure and marketing system for lambs.

Imports and Exports

A discussion on the production and marketing of lamb would be incomplete without investigating imports and exports of live animals and meat. Imports and exports affect flows of product and the marketing system's ability to provide consumers with a product. Concerns over imports have often been the focus of attention in the sheep industry (U.S. ITC, 1995). Given the seasonal nature of lamb production and its overall decline in the U.S., imports provide a supply of meat to consumers when a U.S. product is less available (Stillman et al., 1990). Only long-term import and export trends are presented here. A more detailed analysis of imports and exports are left to a later article (pages 83-91; Anderson and Meyer) in this Special Issue.

Figure 3 shows U.S. production, imports and exports of lamb meat for 1967 through 1995. As shown, the U.S. has been a net importer of lamb meat over that period. While the lamb

Table 4. Major lamb slaughtering states (1972 through 1990).

Year	State	U.S. sheep and lambs slaughtered, %
1972:[a]	CO	18.6
	CA	17.7
	TX	13.6
	NE	9.2
	NJ	8.0
	IA	4.7
	IL	4.6
	SD	4.3
	UT	4.2
	MI	4.1
U.S. total *(1,000 head)*		9,799
1985:[b]	CO	20.1
	CA	19.0
	IA	13.7
	TX	10.6
	MN	7.1
	SD	5.4
	MI	4.8
	IL	4.1
	NM	3.3
	WA	2.6
U.S. total *(1,000 head)*		6,169
1990:[a]	CO	28.4
	TX	11.2
	IA	10.8
	KN	9.0
	MI	5.3
	IL	4.2
	WA	3.5
	NM	3.1
	SD	2.6
	PA	2.2
U.S. total *(1,000 head)*		5,455

[a] As reported by ASI (1996).
[b] As reported by Scott (1986).

import levels are significantly above export levels, it is important to keep them in the proper perspective with U.S. lamb production. U.S. lamb production trended downward from 600 million pounds (1967) to below 300 million pounds in 1995. Overall, lamb imports as a share of production have ranged from a low of 2% in 1967 to a high of nearly 16% in 1979 (Figure 3). Lamb meat imports were 14% of U.S. production in 1995. Stillman et al. (1990) report that imports have typically varied inversely with U.S. inventory levels.

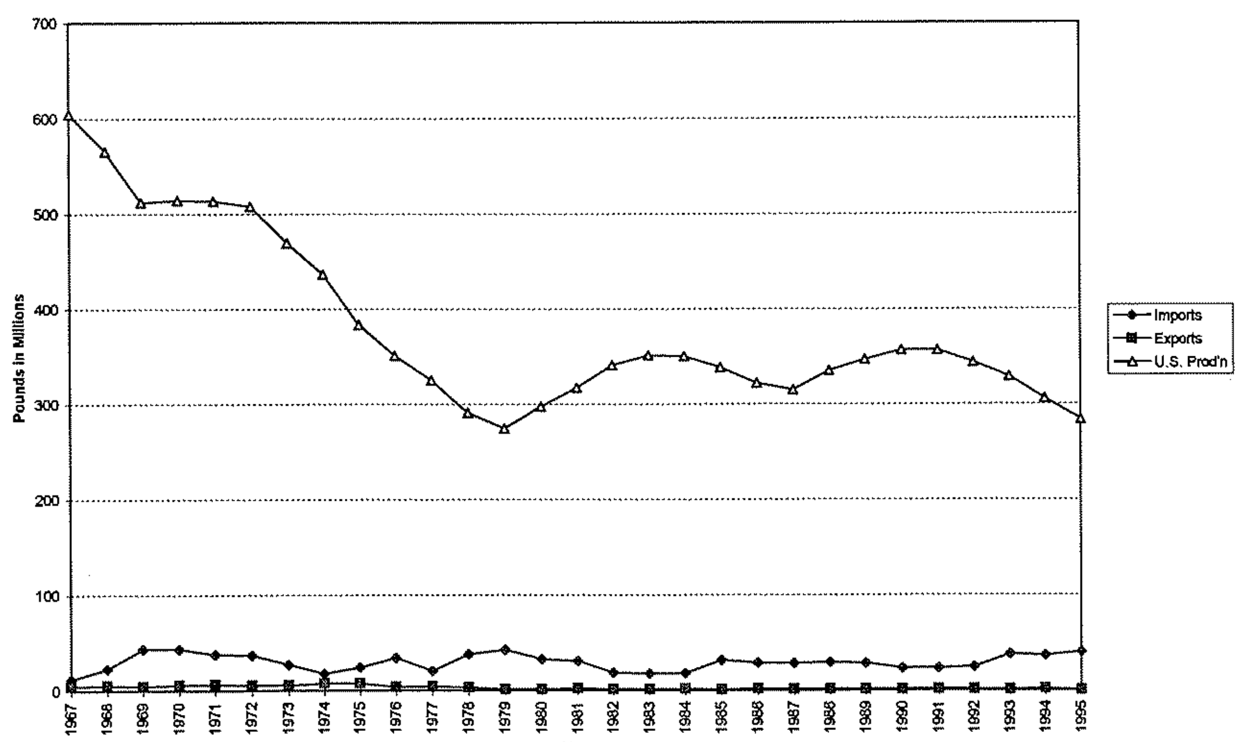
The U.S. also trades live sheep and lambs. Figure 4 depicts trends in live sheep and lamb trade between 1970 and 1995. The U.S. has been a net exporter of sheep and lambs during that time period. Exports have ranged from well below 100,000 head to nearly 850,000 head (Figure 4). The largest increase in live sheep and lamb exports came during the most recent liquidation phase in the sheep inventory. The vast majority of these animals were shipped to Mexico. This large increase in exports was likely influenced by the decision to phase out the wool incentive program.

Wholesale Fabrication, Distribution and Retail Operations

Lamb meat moves from packers or importers to consumers through various wholesale and retail distributors (ASI, 1996). Today's complex and efficient system has evolved with technology and changing production practices and consumption patterns. During colonial days all slaughtering, processing and selling were done primarily by farmers (McCoy and Sarhan, 1988). Most meat was consumed on the farm and any marketable surplus was sold locally. During the second half of the 1800s the introduction of ice packing and refrigeration transformed the meat industry to a year-round business and opened up distant markets. The need for enormous purchases by the government during the Civil War further shaped the wholesale distribution of meat (McCoy and Sarhan, 1988). During the late 1800s some wholesalers also were involved in retailing, but most sold only to retailers and institutions which then sold to consumers. Generally butchers received meat from large packers through branch houses and the consumers then purchased the meat from the butcher.

As the hotel, restaurant and institution or food service sector expanded, the need for other types of wholesalers emerged (McCoy and Sarhan, 1988). By the early 1900s more specialized independent wholesalers known as "breakers," "boners," "purveyors" and "jobbers" had evolved. Agent wholesalers such as brokers and commission firms also increased their role from the 1930s through the 1950s, whereas packer branches declined (McCoy and Sarhan, 1988). From the mid-1950s through the 1970s the meat industry and wholesale and retail distribution entered a new era. Small butcher shops almost disappeared and were replaced by meat departments in supermarkets and chain stores which purchased

Figure 3. United States lamb production: Imports and exports (1967 through 1995).



large volumes of meat (McCoy and Sarhan, 1988).

Wholesale and retail distribution of lamb has followed these general meat industry trends to today's system. This system includes wholesale and retail distributors, including breakers, non-breaker wholesaling firms, retail firms and food service firms (ASI, 1986). Breakers purchase lamb carcasses and boxed primal cuts from packers and sell boxed and further fabricated lamb to wholesale, retail and food service firms. Most breakers are on the East and West Coasts. Of the 30 breakers surveyed by TAMRC in 1991, 47% were located in the Northeast, 20% were on the West Coast (primarily California) and the remaining 33% were scattered throughout the country.

Many lamb wholesalers are general food distributors who handle lamb along with a variety of other food items (ASI, 1996). Many of these wholesalers purchase lamb from both packers and breakers as well as other wholesalers. The two principal markets for non-breaking wholesalers are retail foodstores and food service operations of all types (TAMRC, 1991).

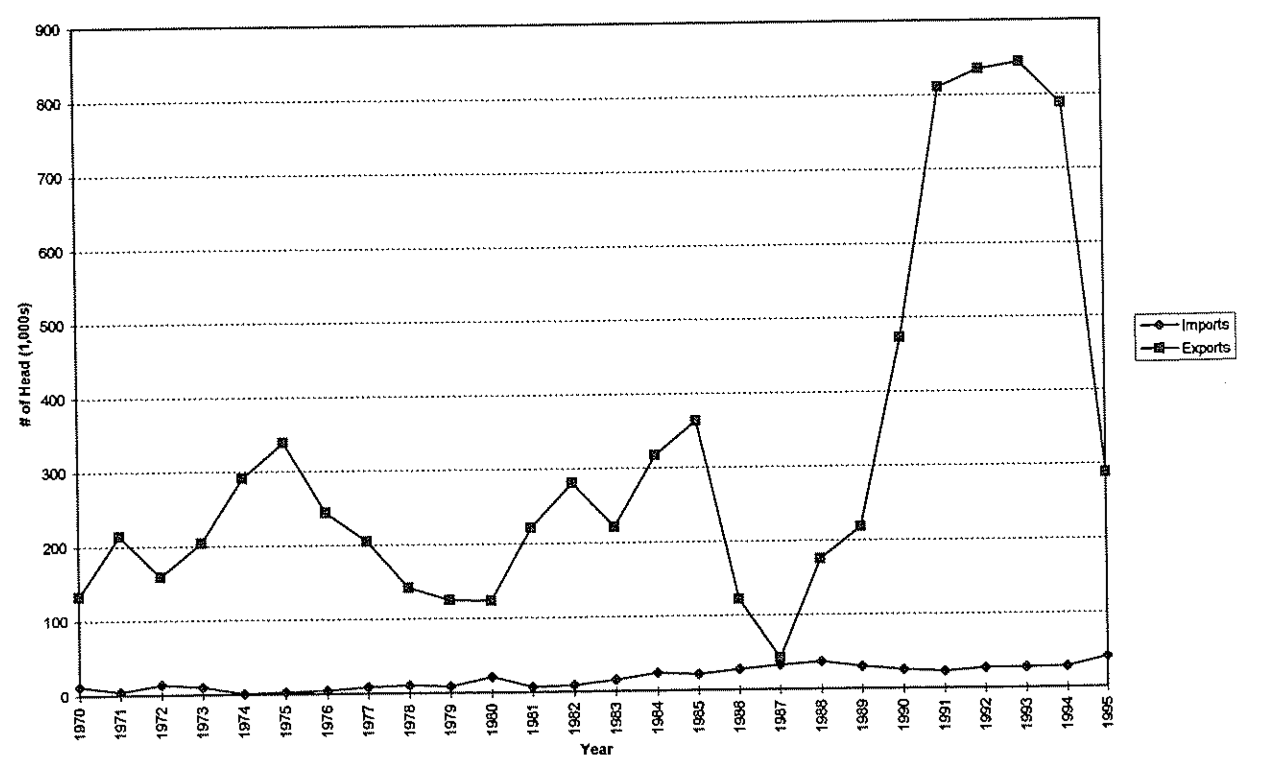
Most lamb purchased by retailers comes from breakers, wholesalers or their own distribution centers. On average, retail foodstores accounted for an estimated 36% of lamb sales of packers, 84% of the sales by wholesalers and 37% of the sales of breakers in 1990 (TAMRC, 1991). The food service industry represents a small but rapidly growing segment of the lamb industry. The food service industry accounted for 8% of packer lamb sales, 15% of non-breaking wholesaler lamb sales and 25% of breaker lamb sales in 1990. The TAMRC (1991) study concluded that the growth of the food service industry and the increasing trend of away-from-home consumption likely accounted for whatever growth might have been achieved in national lamb sales from 1979 to 1989.

Lamb Consumers

If there were no consumers of lamb in this country, sheep production would either return to being primarily for wool production (as it was in the early 1800s) or become non-existent. The lamb industry and segments in the lamb marketing chain have evolved to serve the needs of consumers. Thus, it is the consumer who has likely had the biggest influence on lamb marketing in this country.

The consumption of lamb has been in a long downward trend since World War II. It is not surprising that this decline has played the largest role in the decline of the sheep industry. Between 1900 and 1945, per capita consumption varied between 5.2 and 7.3 pounds (Engelman et al., 1973). The peak in per capita consumption for lamb came in 1945. From 1945 to 1960, lamb consumption fell from 7.3 to 4.8 pounds per capita. Figure 5 depicts a downward trend in per capita consumption of lamb and mutton between 1960 and the mid-1970s. Since the late 1970s per capita

Figure 4. Live sheep and lambs: Imports and exports (1970 through 1995).



consumption has remained relatively stable ranging between 1.2 and 1.5 pounds. Per capita consumption has fallen 84% since the peak in 1945.

Per capita consumption is only part of the demand relationship. The Law of Demand states that the quantity consumed varies inversely with price, all other things being equal. Thus, you would expect that as prices rise, quantity consumed decreases and vice versa. The price and quantity relationship for lamb from 1970 through 1995 is shown in Figure 6. The graph indicates a steady decline in the demand for lamb over this period. The decline is strongly indicated in the 1980s and again in the 1990s by decreases in quantity consumed even with lower prices. Whipple and Menkhaus (1988) studied the demand for lamb during the period between 1950 through 1987. The authors concluded a significant shift for demand had occurred in the 1980s when compared to the previous years, and the decline was probably due to non-price and income factors, such as health and convenience issues.

The location of consumers has changed very little over time. Prior to 1945, the East and West Coast markets were important consumers for lamb, but consumption was slightly more geographically dispersed. Ensminger (1964) stated that in 1954 the East and West Coasts accounted for 80% of lamb consumption. Engelman et al. (1973) reported similar patterns. New York alone accounted for 31.3% of the consumption in 1970. This concentration of consumption explains the location of breakers when compared to the location of packing plants.

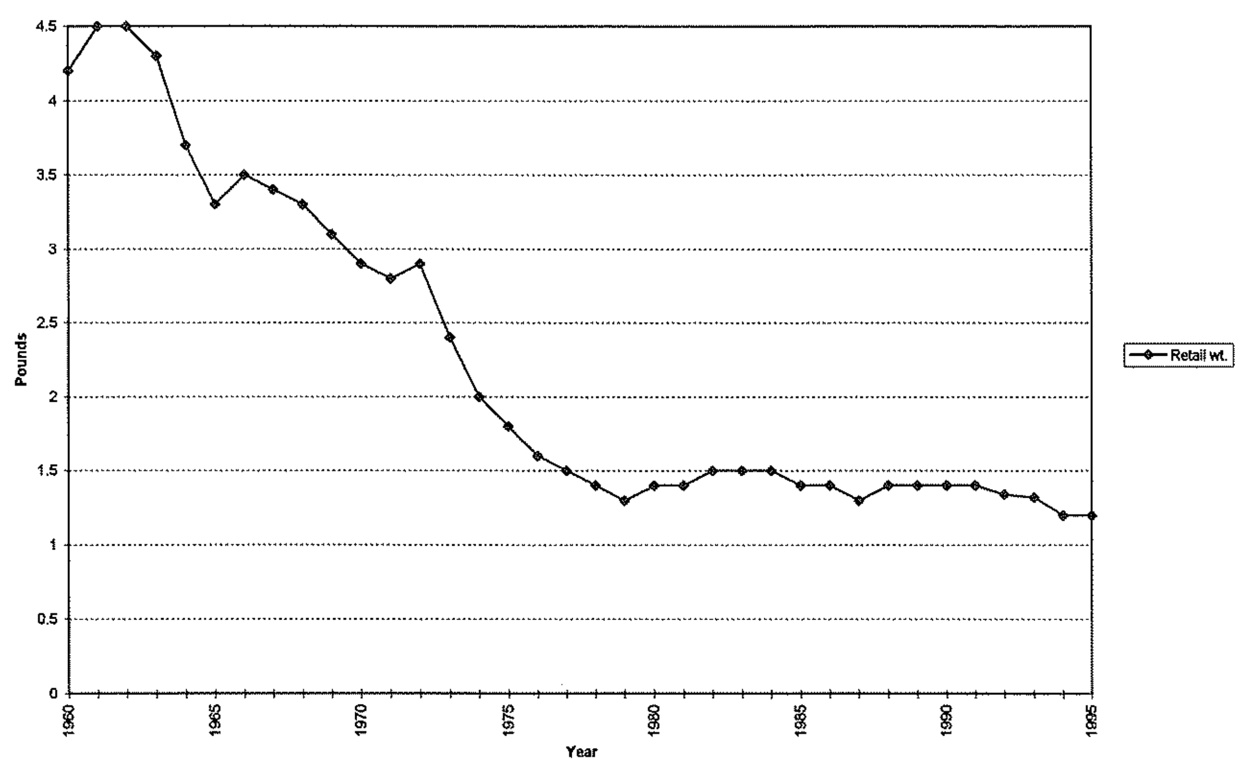
Location and demographics seem to be very important factors in lamb consumption. Lamb consumption is greatest in the Northeastern and Western U.S., and consumers in the Northeast and West are more likely to try lamb than consumers in the South or Midwest (TAMRC, 1991). Lamb consumers seem to fit within an ethnic or racial profile which almost excludes Whites, Blacks and Hispanics (TAMRC, 1991). Increasing age (over 55) and income in the middle to upper levels influence the probability of consuming lamb in this country (TAMRC, 1991).

Approximately 30% of the consuming public have never tried lamb and 24% of the population reported eating lamb at least once a year (Walker Research and Analysis, 1988 and 1989). Nearly 50% of the population have tried lamb at one time in their lives but have not made it a part of their normal diets (TAMRC, 1991). These statistics coupled with the above-mentioned trends and patterns suggest that the lamb industry must address the demand issue. Declining lamb demand has played the largest role in the trends for lamb production and marketing in this country.

Conclusions

The lamb marketing system has changed dramatically over the years. Production of lambs has changed from an emphasis of being produced primarily for wool in the 1800s to meat being of primary importance now. Production moved from the

Figure 5. Per capita consumption of lamb and mutton (1960 through 1995).



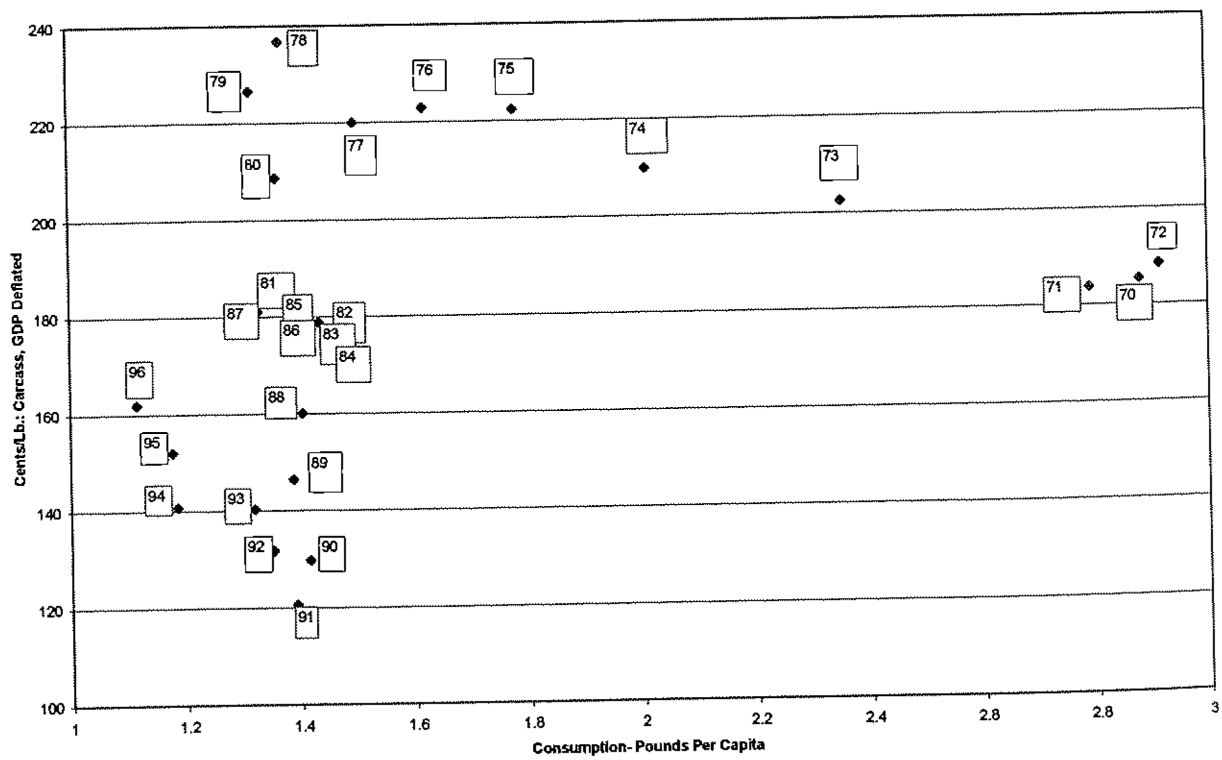
East to the West as inexpensive western range became available in the later 1800s. Production in the 20th century peaked in 1942 and has declined to a level reminiscent of the early 1800s. As production has since declined, lamb feeding and lamb slaughter has declined and become more concentrated regionally. Concentration in the lamb packing industry has historically been relatively high compared to other species in the meat industry, but it has become even more so in recent years. The impacts of that concentration are not well understood. Perhaps the most disturbing implication of this increased concentration is the indication of decreased market infrastructure. The U.S. has been a net importer of lamb meat for many years. Imports represented between 2 and 16% of U.S. production over the years examined (1967 through 1995). The U.S. also has been a net exporter of live sheep and lambs during that same time period. Wholesale and retail operations for the lamb marketing system have become more complex since the beginning of this century as technology, production and consumption has changed. It is the lamb consumer which has driven many of these changes. Lamb has faced a seriously declining demand since 1945 which likely provided much of the impetus for decreased production.

The industry must address the serious decline in demand. Innovations in products which are convenient and unique need to be the focus of those efforts given the relatively high retail price of lamb. This will be more difficult for the industry as a whole given the lack of promotional dollars now available to the American Sheep Industry. If the demand issue is not addressed in a serious manner, it seems likely the trends in declining production and market infrastructure will continue.

Given the deterioration of the market infrastructure for lamb, it seems that more coordination across the segments could help make the system more efficient and responsive to consumer demand. Cooperatives and strategic alliances could help the industry as well as the lamb producers. Coordinated ventures could also explore possible product development and promotion strategies which would be beneficial to consumers and ultimately to the industry.

It is important to remember that international trade is motivated by profit, and producers and consumers are both affected by international trade (McCoy and Sarhan, 1988). Lamb meat imports have helped supply consumers with lamb, and if loyal consumers of lamb were unable to purchase lamb it could mean a permanent loss of a customer. The sheep industry needs every consumer to which it can market lamb. Live sheep and lamb exports have likely helped prices to producers over the years. Efforts spent on demand will ultimately benefit the industry more than efforts spent addressing the importation of lamb meat. International trade is an important part of the lamb industry in the U.S., but import and export levels must be kept in the proper perspective of supply and demand for lamb in this country.

Figure 6. Lamb demand: Price-to-quality relationship (1970 through 1996).



Individual producers should consider joint or cooperative efforts with other producers which can help them gain market power and coordination. These efforts could help alleviate or overcome some of the pricing issues of concern. Also such groups could help promote the industry as a whole. Producers face a specialty market environment for lamb given the trends in demand. This implies that some niche marketing efforts might be fruitful for individuals or groups of producers. This type of strategy requires additional time and resources as well as marketing expertise along with the traditional knowledge of the production side of the business (Bastian and Menkhaus, 1997). Overall, it would seem that increased cooperative promotional and marketing efforts by individual producers will be important for the long-term survival of the industry.

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Lamb Market Structure[1]

Gary W. Williams[2,3] and Ernest E. Davis[4]

Summary

The structure of the U.S. lamb industry has been shaped by numerous factors, including: 1) decades of steady decline in consumer demand for lamb; 2) unique demographic characteristics of lamb demand; and 3) increasing concentration of packing and also feeding to some extent. These factors have created increasing difficulties for value preferences to migrate from consumers to producers, undermining the vitality of the industry. Efforts to revitalize the industry have so far proved less than satisfactory including legal and legislative bids to reduce the level of concentration in the industry and attempts to establish a national lamb checkoff program to fund demand promotion programs. In recent years, producers have turned increasingly to cooperative ventures in an effort to turn their fortunes around.

Key words: lamb markets, structure, value-based marketing.

Introduction

The marketing channel for U.S. lamb is anchored at both ends by relatively large numbers of individuals (Figure 1). At the front end (pulling) are consumers who ultimately determine how much of the available lamb that is consumed at prevailing market prices and, therefore, how much lamb moves through the system at what time of the year. At the other end (pushing) are numerous producers spread out all over the country who raise and market sheep and lambs. The center of the channel is quite narrow in places, however, with relatively few firms involved in changing the form and adding value to the lamb at particular stages as it makes its way from one end of the system (producers) to the other (consumers). The closer the lamb moves to the retail level, the greater the number of firms involved in handling, fabricating and distributing the product. At the producer end, however, fewer firms are involved and the marketing channel is narrower.

In any market system, the demand (pull) of consumers sends signals down through the system to producers regarding the quality, quantity and value characteristics of the products they want to purchase. How well the signals are transmitted down through the system, however, depends to a large extent on the structure of the market, including: 1) the number of levels through which the product must pass; 2) the number and types of groups involved at each level; and 3) the functions each group performs at each level. In general, the fewer the number of levels through which the product must pass and the larger the number of participants at each of those levels, the more efficient markets are at translating and transmitting signals from consumers to producers. In the lamb industry, consumer-to-producer communication is weakened by the multiple levels through which the product passes, by the fact that certain market functions have become concentrated in the hands of a few firms and by the relatively few consumers at the front end pulling.

Commercial lamb feeding has become concentrated geographically over the years among fewer feeders. Although 12 states had 100,000 or more lambs on feed in 1966, only 5 states had at least that many on feed in 1994. Also, 6 states accounted for 54% of the lambs fed in 1966, whereas only 4 states (Colorado, California, Wyoming, Texas; in descending order) accounted for 63% of lambs on feed in 1994. At the same time, the ownership of lambs on feed has become concentrated in the hands of fewer and larger commercial feeders. The number of lambs fed on a custom basis increased markedly in 1990 when a major packer decided to discontinue feeding.

Slaughter lambs move from commercial feedlots and directly from farm flock and range sheep operations to

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packers. Over time, packing operations have declined in number and increased in size. While the four largest packers accounted for about 52% of total lamb slaughter in 1984, they accounted for about 83.0% in 1995.

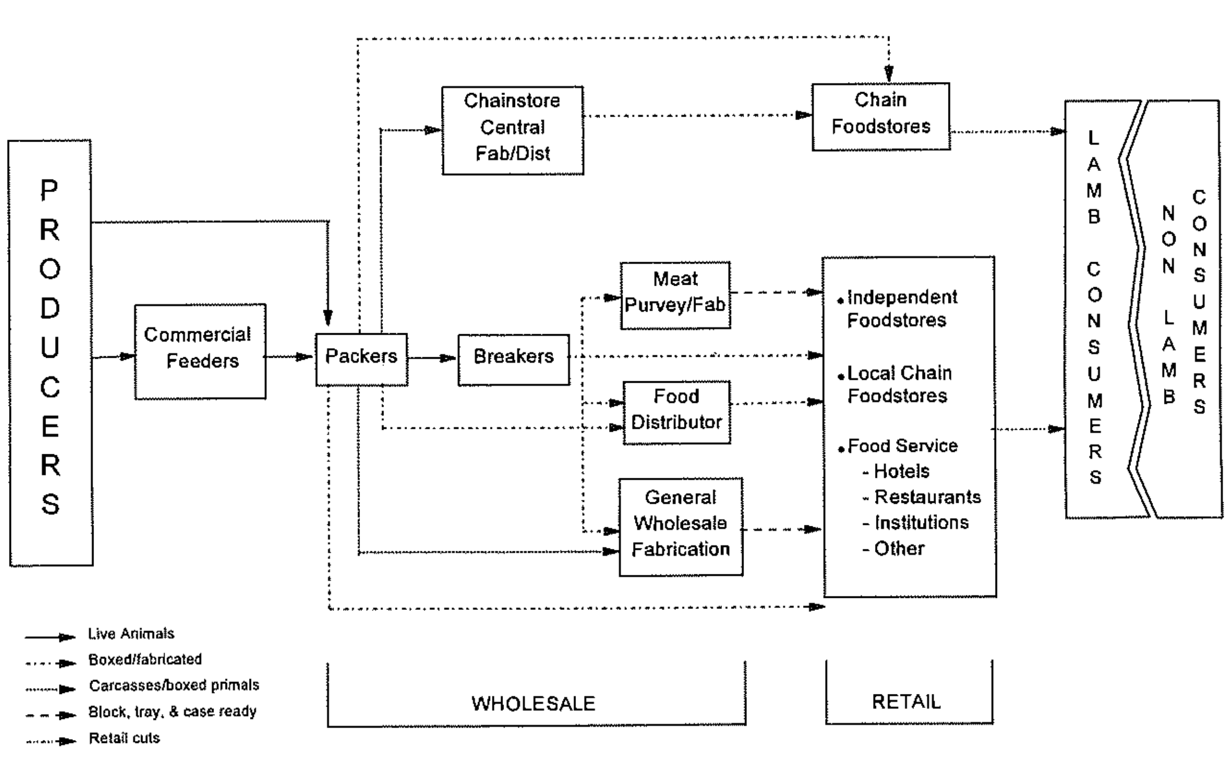
From packers, lamb moves primarily as carcasses or boxed primals and increasingly as boxed subprimals and further fabricated cuts into **wholesale fabrication and distribution**, which includes the central fabrication and distribution centers of major national retail chains, breakers and many non-breaking wholesale distributors and fabricators closer to consumer markets on both coasts. Packers are increasingly servicing retail outlets and food-service establishments directly with boxed primals, subprimals or further fabricated cuts.

A large portion of lamb carcasses flows from packers through **breakers**, primarily on the East Coast but also on the West Coast where consumers are concentrated. The basic function of breakers is to cut carcasses into primal, subprimal and further fabricated cuts for distribution to wholesale and retail operations. Breakers are a major source of fresh lamb for a large number of small to large non-breaking wholesalers, including **meat purveyors/fabricators, food distributors** and **general wholesale fabricators**. Some of the lamb procured by national retail food chains moves through breakers as well (about 10 to 20% according to industry sources). Breakers are also moving further fabricated lamb directly to smaller, local retail operations in many areas in competition with their own wholesale customers.

Retail operations handling lamb include not only large **retail chainstores** but also many **regional/local retail chains, independent food retailers** and numerous **food service operations** such as hotels, restaurants, institutions (HRI trade) and the government. Although the retail operations are many, lamb normally represents a very small part of sales for these establishments. For example, lamb typically represents no more than 1 to 2% of the fresh meat cases of retail foodstores of all types.

In any market system, **consumers** create the value that must be transmitted through the system. In the lamb market, relatively few consumers with specific characteristics are creating the current value of lamb at retail. According to recent research, only 24% of consumers can be considered "lamb consumers" (i.e., have eaten lamb within the last twelve months) as compared to 95% for beef, 94% for poultry and 81% for pork (Walker 1988). In addition, lamb consumers tend to come from ethnic backgrounds (i.e., Jewish, Italian, Greek, Muslim, etc.) and are highly concentrated geographically, largely in the Northeast and the West Coast. These lamb demand characteristics have defined a small but relatively steady demand pull that is quite seasonal in nature. There is a growing trend toward consumption of lamb away from home with food service establishments reporting increased demand for racks and, to a lesser extent, loin chops.

Figure 1. Marketing channels for United States lamb.



Lamb Marketing Channels

To better understand the lamb marketing channel and the functions of each participant, the major segments in the lamb marketing channel are discussed in more detail below.

Sheep and Lamb Production

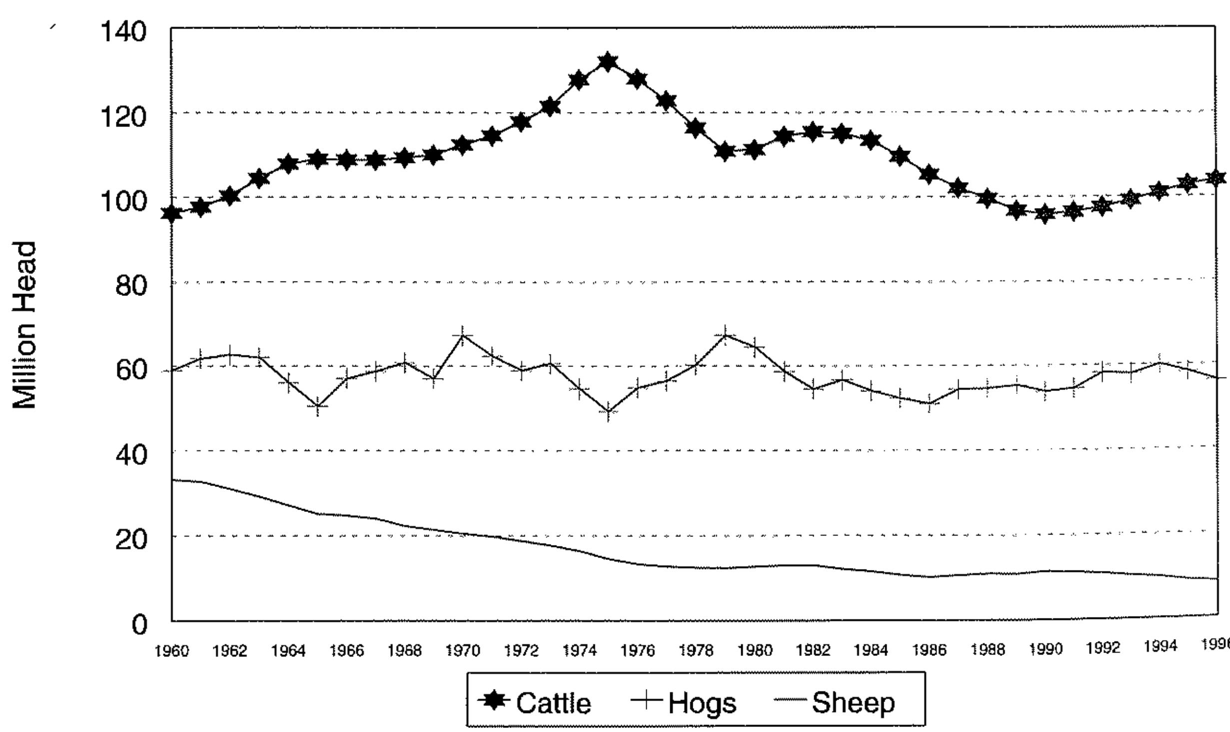
The importance of sheep and lambs to U.S. agriculture has declined dramatically over the past five decades. Sheep numbers have declined nearly 86% since the 1942 peak of 56.2 million head to 7.94 million head in 1997 (Figure 2). The 1940s peak reflected a high demand for wool during World War II for military and industrial usage. With the subsequent development of the synthetic fiber industry, the sheep industry faced a declining wool demand, leading to an emphasis on the production of sheep and lambs for meat rather than for wool. The secular decline of the sheep industry since the 1940s has also been attributed to many other factors, including: 1) lower returns and higher risks relative to other livestock and crop enterprises; 2) high wages and scarcity of qualified sheep herders; 3) uncertainties in U.S. and foreign trade policies; 4) discontinuation of the U.S. wool incentive payment program; 5) grazing allotment policies for public lands; 6) restrictions on predator control; 7) greater technological development in competing meat processing industries, particularly poultry and pork; and 8) shifts in consumer tastes and preferences toward leaner meats without the distinct flavor often associated with lamb.

There were about 77,010 sheep operations in 1996 (i.e., operations with at least one head) and 7.94 million head of sheep. The top ten lamb producing states in 1996 accounted for 69% of all U.S. lambs (Table 1). The top ten sheep producing states included: Texas (TX; 17.6%), California (CA; 12.1%), Wyoming (WY; 9.1%), Colorado (CO; 7.2%), South Dakota (SD; 5.7%), Montana (MT; 5.4%), Utah (UT; 4.7%), Oregon (OR; 3.8%), Idaho (ID; 3.6%) and Iowa (IA; 3.6%). Based on the results of a survey conducted by the Texas Agricultural Market Research Center (TAMRC) in 1991, an estimated 70 to 90% of the lambs are sold as feeder lambs with the remaining 10 to 30% going directly to packers without passing through commercial feedlots (Figure 3). Producer sales of slaughter sheep and lambs to packers either directly or through some type of public market, however, represent 27% of slaughter sheep and lamb purchases by packers according to the survey results (Figure 4).

There are four kinds of sheep operations in the U.S.: 1) range band for public grazing areas; 2) fenced range systems; 3) farm flock; and 4) purebred sheep. The first two categories are located almost entirely in the 17 Range states where there are large amounts of untillable public and private native pasture land (NM, AZ, CA, WA, OR, UT, NV, ID, MT, WY, CO, TX, OK, KS, NE, SD, ND). Herd sizes on both types of range operations vary from less than 100 head to more than 10,000 head. Often the sheep enterprise on these operations is the primary source of income.

Range band operations are typically located in the 11 Western states and

Figure 2. United States livestock inventory (1960 through 1996).



South Dakota where there are vast areas of unfenced public grazing lands. Since the majority of the land utilized by range band operations is unfenced, unimproved, native high-mountain and desert pastures, range bands often must move long distances from season to season and thus require on-site herders (Ensminger, 1986). The range band method of sheep production is likely to decline in importance due to tighter government controls over public grazing lands and increases in public grazing fees. The **fenced range** method is used mainly in Texas, New Mexico, Oklahoma, Kansas, Nebraska and North Dakota where there is relatively less publicly-owned land and the ranges are mostly fenced. Unlike range band sheep operations, fenced range producers do not normally utilize on-site herders (Ensminger, 1986).

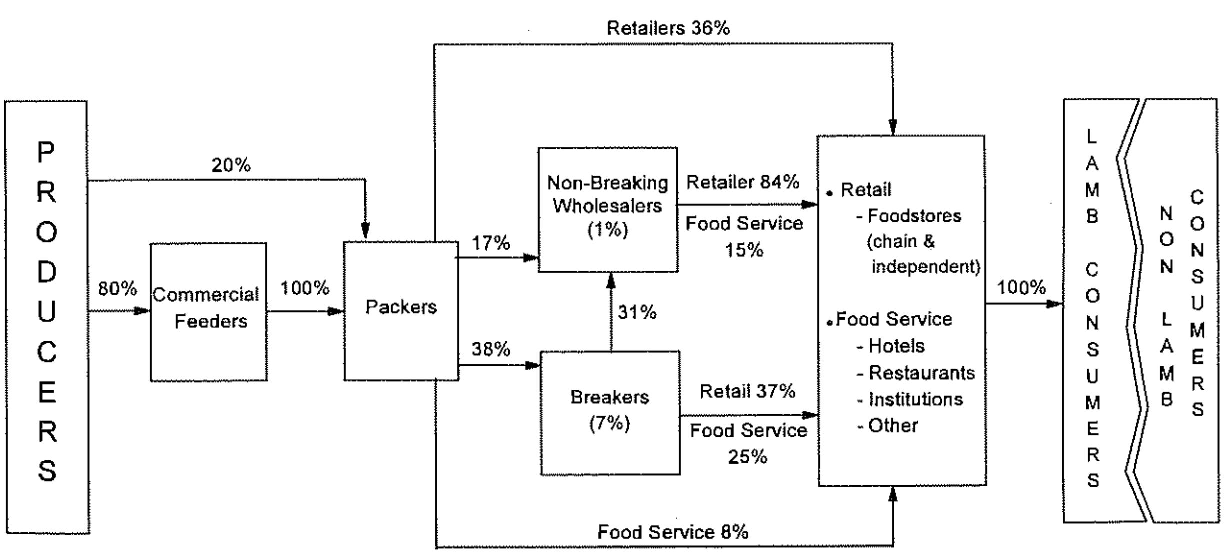
Table 1. Top ten sheep producing states (1997).[a]

State	Sheep and lamb numbers, 1,000 head	Sheep operations, number	Sheep per operation, head
TX	1,400	7,000	200
CA	960	4,600	209
WY	720	1,100	655
CO	575	1,300	442
SD	450	2,700	167
MT	432	2,200	196
UT	375	1,700	221
OR	304	2,600	117
ID	285	6,000	48
IA	285	1,100	259
10-state total	5,786	30,300	*Average:* 191[b]
U.S. total	7,937	77,010	*Average:* 103[c]
% of U.S.	73	39	185[d]

[a] As of January 1 of 1997. (Source: USDA, 1997c.)
[b] Ten-state average number of head per farm.
[c] United States average number of head per farm.
[d] Ten-state average as a percentage of the United States average.

The 17 Range states accounted for 81.5% of all breeding ewes and 76.9% of the lamb crop in 1996 (Table 2). The majority of lambs produced on range operations require additional feeding to reach slaughter weight. The percentage of Western lambs that go on feed depends primarily on weather conditions in the range areas. During drought periods, lambs coming off the range tend to be smaller and are normally sold to lamb feeders. Some range producers, however, feed their own lambs and sell them as finished slaughter lambs directly to packers. Smaller producers usually sell their lambs at a public auction, directly to packers or through intermediaries. Packers often prefer to purchase slaughter lambs by the truckload (about 400 head) to minimize

Figure 3. Lamb sales through market channel (1990).[a]



[a] Derived from survey data collected by the Lamb Study Team.

transportation costs and usually pay a higher price per head for a truckload of lambs than for lambs in smaller groups. An intermediary will often consolidate small lots of lambs at a lower price and sell truckloads to packers at higher prices. Larger lamb producers have traditionally sold their lambs by contract directly to feeders and/or packers while the smaller producers have tended to sell their lambs at public livestock auctions. Currently, many range-produced sheep are marketed at public livestock auctions. The shift to heavier use of such auctions by many range band sheep producers, particularly in Texas and South Dakota, is likely the result of a decrease in herd size. Few producers are now capable of selling enough lambs to offer truckloads of uniform size lambs to feeders and packers and consequently may receive lower net prices.

Farm flock operations are found throughout the U.S. but predominate in the midwestern and eastern states. About 23% (1.2 million head) of the 1996 lamb crop was produced in the farm flock states (Table 2). Farm flocks range from a few to over 1,000 breeding ewes. Most farm flock sheep producers derive their primary income from sources other than the sale of sheep. They raise sheep to utilize otherwise unproductive land or supplement income or strictly as a hobby. The majority of farm flock lambs are fattened on the farm and sold as slaughter lambs at public auctions.

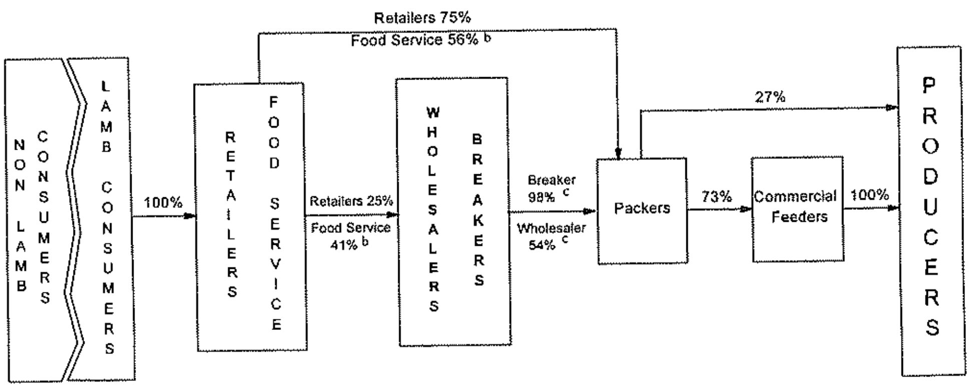
Purebred sheep operations are located throughout the sheep

Table 2. Breeding ewes and lamb crop in the Range states (1995 and 1996).[a]

	Breeding ewes (≥ 1 year), 1,000 head		Lamb crop, 1,000 head		Lambs per 100 ewes, number	
	1995	1996	1995	1996	1995	1996
U.S. total	5,300	5,128	5,606	5,282	106	103
11 Western states[b]	2,547	2,469	2,641	2,522	104	103
% of U.S.	48.1	48.1	47.0	47.7	98.1	100.0
17 Western states[c]	4,298	4,177	4,332	4,063	101	98
% of U.S.	81.1	81.5	77.3	76.9	95.3	95.1

[a] As of January 1 of each year. (Source: USDA, 1997c.)
[b] Includes: NM, AZ, CA, WA, OR, UT, NV, ID, MT, WY, CO.
[c] Includes: "11 Western states" plus TX, OK, KS, NE, SD, ND.

Figure 4. Lamb demand through market channel (1990).[a]



[a] Derived from survey data collected by the Lamb Study Team.
[b] The other 3% of Food Service is intra-food service purchases.
[c] The other 2% of Breakers is intra-breaker purchases.
[d] The other 46% of Wholesalers is purchased from other wholesalers (20%) and breakers (26%).

producing states. Some producers maintain small purebred flocks as well as large commercial herds for the production of purebred breeding rams for sale or replacement, purebred ewes for sale to other producers and for showing. Others specialize in purebred sheep production.

Lamb Feeding

At the beginning of 1997, 2.09 million sheep and lambs were classified as market sheep or lambs in the U.S., about 26% of all U.S. sheep inventories (Table 3). The U.S. sheep industry is predominately a ewe/lamb operation as 61% of the total sheep numbers in inventory at the beginning of 1997 consisted of breeding ewes. Since lambs are usually on feed for only 1 to 3 months, 2 to 4 times the number the sheep on feed at any one time are normally fed in the course of a year.

Over 96% of market sheep and lambs are produced in 25 states. The majority of the sheep feeding industry (81%), however, is concentrated in ten states (CA, CO, TX, WY, OR, IA, SD, AZ, MN, KS). More than 50% of the lambs are fed by fewer than ten commercial feeders with operations mainly in Colorado, California, Texas and Wyoming. Some of the large lamb feedlots are owned and operated by meat packing companies while others are independently owned and operated. Although 100% of commercial feedlot sales of slaughter sheep and lambs are to packers, those sales represent only 73% of packer purchases since 27% of what they purchase comes directly from producers as milk fat lambs according to the results of the TAMRC survey (see Figures 3 and 4).

The lamb feeding industry is characterized by both feedlot and field finishing operations. The majority of the drylot operations are located in Colorado, Kansas, Texas, Wyoming and the Midwestern states. The pasture operations are concentrated in California, Oregon and Washington. Feedlot operations usually feed sheep year round with some seasonal changes in numbers on feed. Pasture feeding operations are even more seasonal in nature (Dietrich et al., 1990). Lamb feeding arrangements between producers, feeders and packers vary widely depending on availability and location of feed, condition of feeder lambs and the type of carcass demanded by packers.

Custom lamb feeding has become increasingly common, particularly in Colorado, Wyoming and Texas, since 1989 (Dietrich et al., 1990). In custom feeding, a producer, packer or other feeder retains ownership of the

Table 3. Sheep inventory in 25 major sheep feeding states.[a]

State	Total sheep, 1,000 head	Market lamb and sheep: Number, 1,000 head	% of state	% of U.S.	Breeding ewes (> 1 year): Number, 1,000 head	% of state	% of non-market
AZ	125	75	60.0	3.6	44	35.2	88.0
CA	960	480	50.0	23.0	380	40.0	79.0
CO	575	325	57.0	15.6	210	36.6	84.0
ID	285	40	14.0	1.9	204	71.6	83.0
IL	79	10	13.0	0.5	57	72.0	83.0
IN	67	12	18.0	0.6	45	67.2	82.0
IA	285	97	34.0	4.6	153	53.7	81.0
KS	150	50	33.0	2.4	84	56.0	84.0
MI	98	33	34.0	1.6	53	54.0	82.0
MN	180	50	28.0	2.4	105	58.0	81.0
MO	68	13	19.0	0.6	44	65.0	80.0
MT	432	32	7.0	1.6	330	76.4	83.0
NE	95	18	19.0	0.9	65	68.0	84.0
NV	85	11	13.0	0.5	54	64.0	73.0
NM	235	15	6.0	0.7	180	77.0	82.0
ND	135	30	22.0	1.4	91	67.0	87.0
OH	130	29	22.0	1.4	80	61.5	79.0
OK	75	15	20.0	0.7	52	69.0	87.0
OR	304	95	31.0	4.6	165	54.0	79.0
SD	450	95	21.0	4.6	310	69.0	87.0
TX	1,400	250	18.0	12.0	980	70.0	85.0
UT	375	36	10.0	1.7	290	77.0	86.0
VA	80	15	19.0	0.7	51	64.0	78.0
WI	69	12	17.0	0.6	44	64.0	71.0
WY	720	170	24.0	8.1	450	82.0	82.0
25-state total	7,457	2,008	27.0	96.2	4,521	60.6	83.0
U.S. total	7,937	2,087	26.0	100.0	4,836	60.9	83.0

[a] As of January 1 of 1997. (Source: USDA, 1997c.)

lambs but contracts with a feedlot to finish the lambs to a desired weight. Producers who contract with feeders to custom feed their lambs often contract with a packer to deliver slaughter lambs of a certain weight. Producers in the farm flock states at times even supply the feeder with some or all of the necessary feed and dictate how the animals are to be fed.

Packing

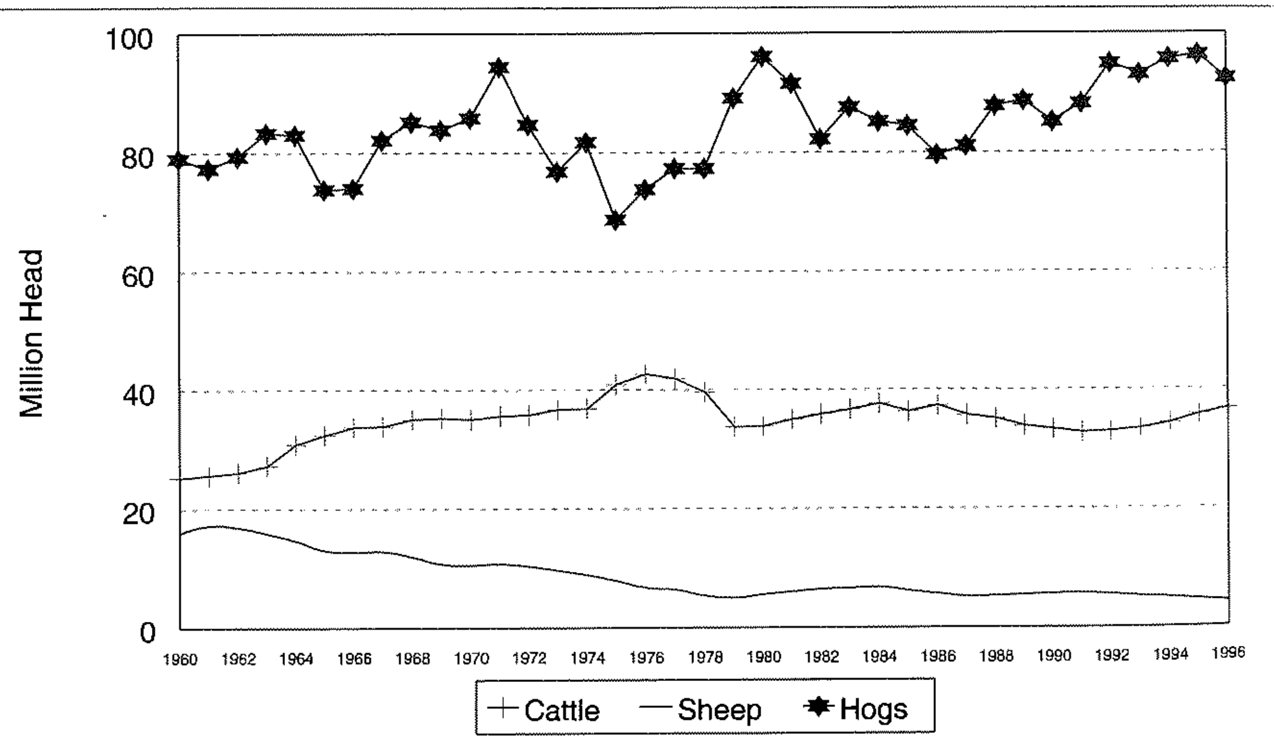
Sheep and lamb slaughter has decreased along with sheep numbers over the past three decades while cattle and hog slaughter have remained relatively constant (Figure 5). Since the early 1960s, sheep and lamb slaughter has declined by about 75%. An increase in carcass weights, however, has meant that the production of lamb and mutton meat has not declined as rapidly as slaughter (Figure 6). As a share of total red meat production, lamb and mutton has decreased from almost 3% in the early 1960s to 0.6% in recent years (Figure 7).

Only 4 states account for about 62% of the lamb meat production (Table 4): Colorado (CO; 31.0%), California (CA; 9.5%), Iowa (IA; 10.7%) and Texas (TX; 10.8%). Most major sheep producing states slaughter only a small portion of the sheep they produce. Most Western and mountain state sheep and lambs flow to California and Colorado for feeding and/or slaughter. In the Midwest, the net flow of slaughter sheep and lambs is to Iowa.

Lamb packing has become increasingly concentrated among a few firms in recent years, surpassing levels of the early 1920s when Congress and others expressed concern about large-scale organization in meat packing. Between 1908 and 1919, the four-firm concentration ratio in lamb packing (the percent of lamb slaughter accounted for by the largest four lamb packing firms) increased from 54.2 to 72.0% (Williams, 1966). The level of concentration remained at about that level through the late 1940s. The 1950s through the 1970s, however, were characterized by decreasing concentration as a number of large packers drastically reduced their lamb operations and many smaller lamb slaughterers began serving smaller geographic areas. In the mid-1980s, however, mergers and acquisitions pushed the four-firm concentration ratio up sharply from about 55% in 1987 to about 75% in 1988 (Table 5). This same concentration among a few packing firms has occurred in the beef industry as well as the lamb industry. The four-firm concentration ratio for beef increased from about 59% in 1979 to an estimated 81% in 1996 (American Sheep Industry [ASI] Association, 1991a).

The traditional function of lamb packers has been to slaughter animals and ship hanging or boxed carcass equivalents to breakers or others for further processing. Much of the initial breaking and boxing of primals and subprimals, however, is increasingly being done by the packer. An estimated 30% of sheep and lamb carcass breaking was done by packers in 1990. Because one packer recently began to box a large portion of the lamb they produce, the percentage of the initial breaking done by packers jumped to about 65% to 70% in 1991 (ASI, 1991b). Based on the TAMRC survey results, breakers represented only about 38% of packer lamb sales in 1990 (refer to Figure 3). Another

Figure 5. United States livestock slaughter (1960 through 1996).



36% went directly to retailers of various types, mostly large corporate retailers. The remainder of packer sales went to wholesalers of various types (17%) and directly to various food service operations (8%).

Breaking

Breakers act as middlemen, purchasing lamb carcasses and boxed primals from packers and selling boxed and further fabricated lamb cuts to wholesalers and retailers. According to the TAMRC survey data, 31% of breaker lamb sales in 1990 went to wholesalers/further fabricators, 37% to retailers of various types (mostly small local independent

Figure 6. Sheep and lamb average carcass weight (1960 through 1996).

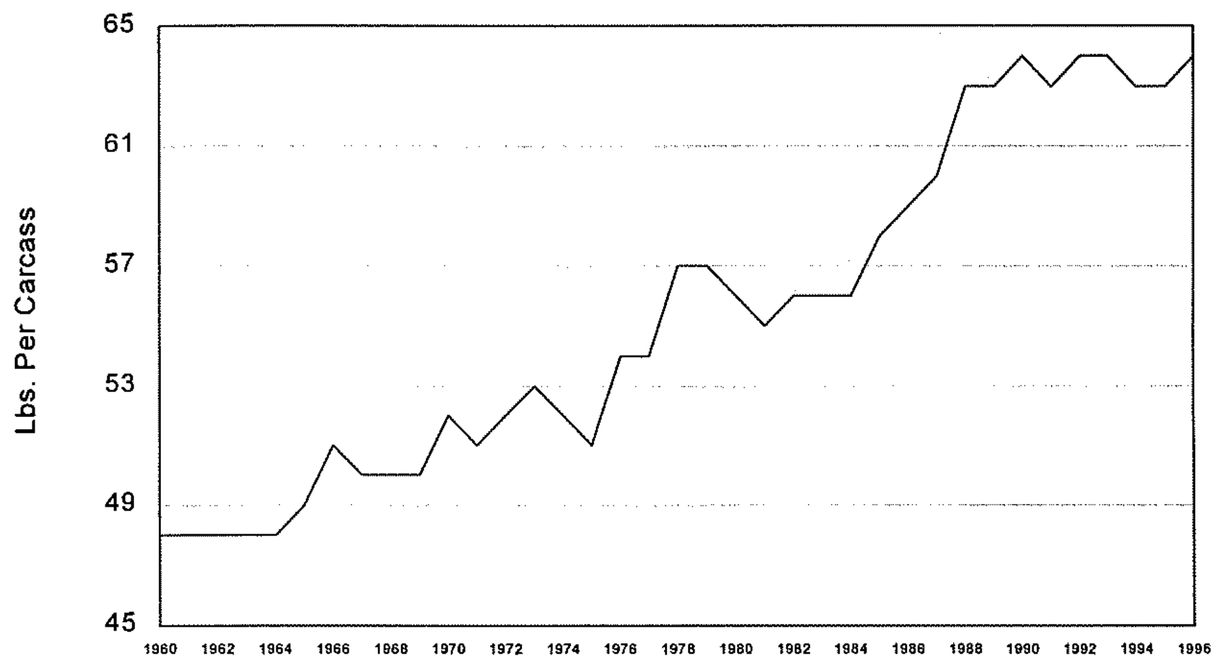
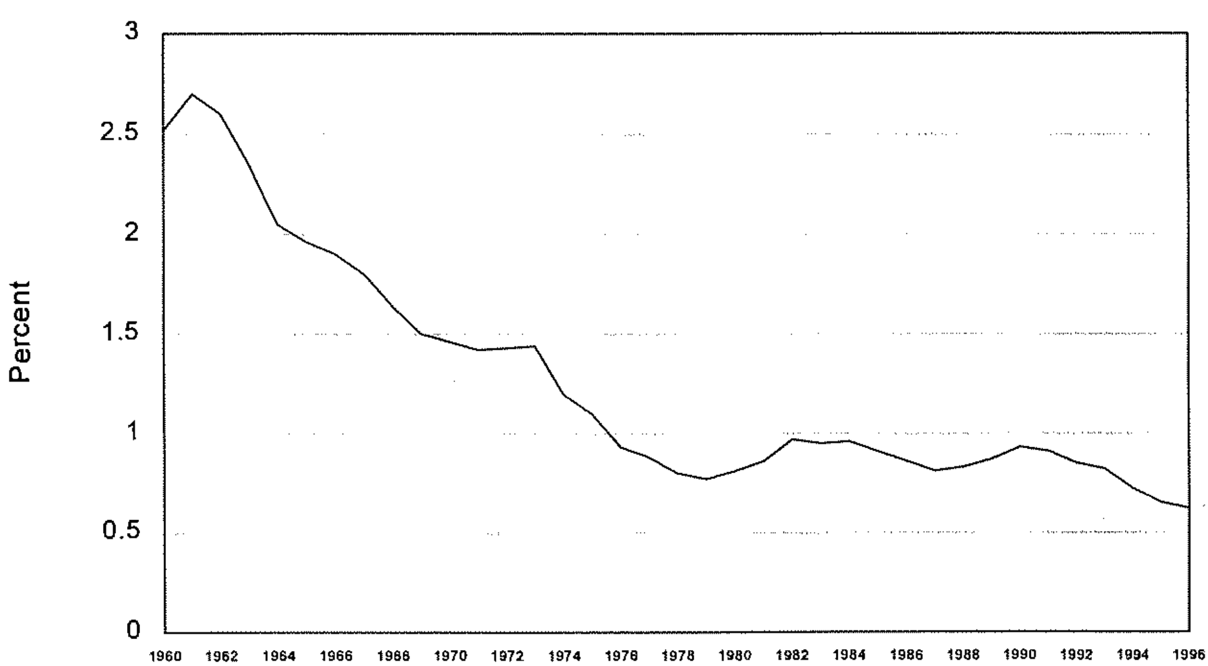


Figure 7. Lamb/mutton share of United States red meat production (1960 through 1996).



and chain operations) and another 25% to food service operations (see Figure 3). The other 7% was intra-breaker trade. Of the 30 breakers in the TAMRC survey sample, 47% are located in the Northeast from Boston to Philadelphia, 20% are on the West Coast (mainly California) and the remaining 33% are spread out over the country – predominantly in the Midwest, Lake and Mountain states. Little other official information is available on the location, capacity or other characteristics of lamb breakers.

The role of the breaker in the lamb marketing system has been somewhat controversial and not well understood. The existence of breakers and the profitability of the lamb breaking function are mainly due to the geographical distance between major lamb consumption centers and packers and the low volume of lamb handled by the relatively large number of food wholesalers and retailers in those major consuming areas. By locating in or near the major lamb consumption areas, breakers can provide service and convenience to buyers while packers may be too far removed to service them efficiently. Because lamb represents only a very small part of the food or meat business of most food wholesalers and retailers, only a few of them buy lamb in volume. Also, many food service groups, local retail chains and others only want to purchase certain cuts. Even large retailers who buy in

Table 4. Commercial sheep and lamb slaughter by major state (1997).[a]

	Slaughter		Meat production	
State	1,000 head	%	1,000 pounds	%
CA[b]	–	–	67,224	9.5
CO	1,546.9	36.4	219,328	31.0
IL[b]	–	–	31,748	4.5
IA[b]	–	–	75,711	10.7
KS	2.0	0.004	55,403	7.8
MI	224.3	5.2	33,538	4.7
MN[b]	–	–	7,013	1.0
NJ	126.2	2.97	6,986	1.0
NM	43.4	1.02	20,291	2.9
NY	34.0	1.6	10,277	1.4
PA	67.8	1.6	12,337	1.7
SD	189.6	4.5	18,317	2.6
TX[b]	–	–	76,539	10.8
WA[b]	–	–	22,536	3.2
14-state total[c]	–	–	685,271	96.8
U.S. total	5,654.0	100.0	708,205	100.0

[a] Source: USDA, 1997a.
[b] State slaughter data not printed to avoid disclosing individual operation; states without printed data are still included in the "U.S. total."
[c] "14-state total" slaughter information not available at this time.

Table 5. Market shares of major lamb packers (1984 through 1990 and 1994).[a]

	Year, %[b]							
Firm	1984	1984	1986	1987	1988	1989	1990	1994
Wolverine	2.1	1.8	2.4	2.2	3.0	2.7	3.4	4.2
Morrell	7.5	–	8.3	8.3	–	1.4	2.6	4.9
Farmstead	7.0	7.5	7.3	7.3	7.6	6.1	1.0	–
Denver/Iowa	**21.1**	**27.5**	**21.5**	**21.5**	**21.6**	**19.1**	**20.5**	**12.9/13.5**
Superior	**10.3**	**9.8**	**10.0**	**10.0**	**12.5**	**14.9**	**16.3**	**15.7**
Armour	9.0	**8.9**	6.9	6.9	–	–	–	–
Colorado	9.3	8.0	**14.8**	**14.8**	–	–	–	–
Swift	**11.6**	8.5	8.8	8.8	3.4	–	–	–
Rocco	–	–	2.4	3.4	–	–	–	–
Kansas	–	–	7.0	7.0	–	–	–	–
ConAgra	–	–	–	–	**33.2**	**29.0**	**33.2**	**34.7**
High Country	–	–	–	–	–	**10.4**	**4.1**	–
Chiappetti	–	–	–	–	–	–	–	5.8
Four-firm concentration ratio[c]	52.3	54.7	55.1	55.1	74.9	73.4	74.0	76.8
Total	77.9	72.0	89.4	90.2	81.3	83.6	81.1	91.7

[a] Source: ASI, 1991a.
[b] Blanks ("–") indicate years in which respective firms did not pack lamb; **bold** numbers indicate the four largest shares in each year.
[c] "Four-firm concentration ratio" refers to the total of the four largest annual shares (shown in **bold**).

volume have difficulty utilizing full carcasses or carcass equivalents and often prefer to purchase further fabricated lamb. To reduce the risk of a downturn in the lamb market or to be able to respond quickly to upturns, large retailers normally purchase only about 80% of their projected lamb needs from packers and reserve the remaining 20% to be purchased as needed from local breakers.

The profit for breakers, therefore, comes from buying carcasses in volume, breaking them into pieces and often selling small orders of only the specific pieces desired by many small, medium-sized and even large buyers. They fill orders, deliver quickly and provide the needed inventory and distribution function which the many small/medium-sized firms cannot afford. The breakers also assume the risk of holding inventory and finding markets for carcass parts that are less in demand. Because there are actually only four readily saleable lamb carcass cuts (loins, legs, chucks, racks), retailers that purchase carcasses must either dispose of the less popular portions or severely discount them at retail to move them. Retailers are thus forced to mark up the prices on those cuts that do move in order to cover their losses on cuts that do not. They often find it less costly to simply buy the desired cuts from breakers and let the breakers assume the risk and absorb the cost of selling or disposing of unwanted carcass parts. Another service often provided by breakers is financing. Credit availability for many small and medium-sized meat purveyors and retailers is often a problem in some areas. By providing credit for purchases, breakers are able to move greater volumes of lamb.

The drawback, of course, is that breakers charge for the services and convenience they provide just as corner foodmarts charge more for food products than less conveniently located grocery stores. The consequence is an additional cost added onto lamb before it reaches the consumer. Packers, of course, could perform more of the functions of breakers and some are doing so. The distances involved, the costs of carrying inventory, providing financing, expanding their distribution systems and the inefficiencies in servicing small volume users, however, give many breakers a competitive edge in many regional markets.

Non-Breaker Wholesaling

The lamb wholesaling function (beyond breaking) is highly diversified. Many non-breaking wholesalers are general food distributors who only carry lamb as one of their many food lines. Many provide a full line of food products, including lamb, to food service groups and food retailers. They buy food products from many different manufacturers and consolidate them into groups required by their customers without performing any fabrication. Many of these wholesalers know little about lamb and simply purchase further fabricated cuts required by their customers.

Other general food wholesalers purchase lamb as carcasses or boxed primals and perform some fabrication prior to resale to retail establishments. Many are meat purveyors specializing in meat products. They generally purchase boxed or further fabricated lamb and produce block, tray or case-ready lamb products for retail sale. Many serve relatively small local markets and some perform the retail function.

Non-breaking wholesalers purchase lamb from both packers and breakers as well as other wholesalers, accounting for about 17% of packer sales and 31% of breaker lamb sales (refer to Figure 3). The two principal markets for non-breaking wholesalers are retail foodstores (mostly local and regional chains and independents) and food service operations of all types. Food service accounts for an estimated 15% of lamb sales by non-breaking wholesalers with retailers accounting for 84% (refer to Figure 3). The remaining 1% is intra-wholesaler trade.

Retailing

Any establishment which directly serves the consumer is considered to be a retailer. Defined in this way, retailers vary widely in type and include: 1) large national chain foodstores; 2) local chain and independent foodstores; 3) local butcher shops; and 4) food service groups such as hotels, restaurants, healthcare and similar institutions (HRI trade) and even the government. Many retail establishments spread out around the country carry lamb as one of their meat offerings.

Foodstores carrying lamb typically offer 2 to 4 facings of lamb cuts in their meat cases, only about 1 to 3% of their meat cases. Lamb is more prevalent in retail establishments in the high consumption areas of the Northeast and the West Coast. Elsewhere, even in high lamb production areas, lamb can be difficult to find in foodstores and restaurants because of the lack of demand. Several foodstore chains and foodservice groups in the Florida area carry a larger volume and more variety of lamb cuts than is common outside the Northeast and West Coast.

Most lamb purchased by local retailers from breakers, wholesalers or their own central fabrication and distribution centers is block ready. Butchers in each store prepare the lamb for retail sale. Although retail-ready lamb is not commonly available, the TAMRC survey revealed that many retailers would actually prefer to purchase more case-ready lamb if available at reasonable cost. Because lamb represents a small portion of the business of most retail foodstores, the cost of cutting and preparing lamb subprimals for retail sale and of teaching their butchers how to cut and prepare lamb can be higher than the additional cost of purchasing case-ready cuts.

On average, retail foodstores accounted for an estimated 36% of the lamb sales of packers, 84% of the sales of wholesalers and 37% of the sales of breakers in 1990 (refer to Figure 3). On the other hand, retailers purchased three-quarters of their lamb directly from packers in 1990 with the other quarter coming from breakers/wholesalers (see Figure 4). Unfortunately, no data exist to determine the share of consumer lamb purchases accounted for by retailers.

The food service industry (HRI trade, government) represents a small but rapidly growing segment of the lamb industry. The food service industry accounted for 8% of packer lamb sales, 15% of non-breaking wholesaler lamb sales and 25% of breaker lamb sales according to the TAMRC survey results (see Figure 3). Again, no data are available to indicate the share of consumer lamb purchases accounted for by the food service industry. The growth of the food service industry in this country and the increasing trend toward away-from-home consumption of all types of foods over the last two decades likely accounts for whatever growth might have been achieved in national lamb sales during that time.

Lamb Consumption

The peculiarities of U.S. lamb consumption and the particular characteristics of current lamb consumers help explain the market structure and marketing channels in the U.S. lamb industry. The volume of lamb consumed in the U.S. is quite low compared to other red meats and poultry. Although fluctuating somewhat within a narrow band, U.S. lamb consumption has also shown little, if any, real trend over the last two decades (Figure 8). About 30% of the consuming public have never even tried lamb while only 24% eat lamb at least once a year (Walker, 1988 and 1989). That means that the remaining nearly 50% of the population has tried lamb at one time in their lives but have not made it a part of their normal diets for some reason.

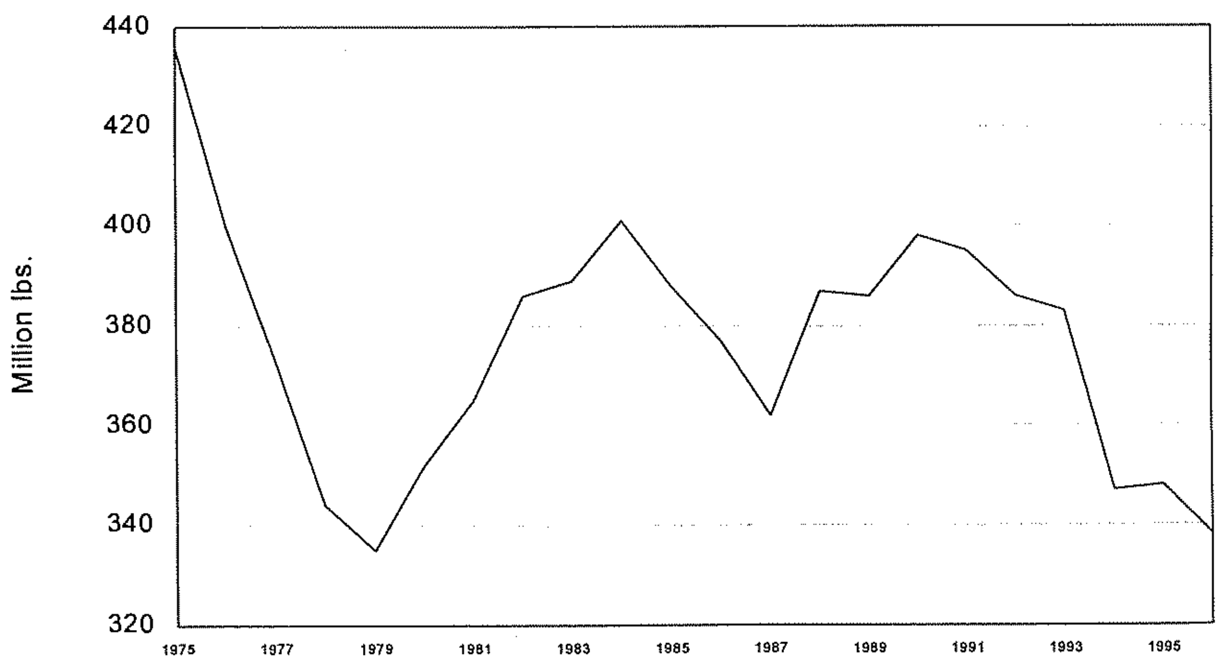
The low volume and lack of trend in U.S. lamb consumption is more apparent when compared to consumption patterns in major lamb consuming countries like Australia (Figure 9). Total lamb consumption in Australia is about double that in the U.S. and has grown over time. U.S. lamb consumption has stayed fairly constant with little relative variation.

Although total U.S. lamb consumption has not grown, the U.S. population has. The consequence has been a slow, steady decline in per capita lamb consumption from over 2 pounds (retail weight equivalent) in 1970 to 1972 to 1.1 pounds in recent years (Table 6). Unfortunately, per capita lamb consumption is far below that of all other meats including beef (67.7 pounds), pork (49.1 pounds), chicken (70.7 pounds), fish and shellfish (15.5 pounds) and even turkey (18.5 pounds).[5] Although the per capita consumption of lamb, pork, and veal has changed little over at least the last decade, beef consumption has declined by over 12% since the early 1980s. Over the same period, however, the per capita consumption of chicken and turkey has increased 43.5 and 76.2%, respectively.

Comparing the per capita levels in the U.S. with those in a major consuming country like Australia illustrates clearly the low level and stability of U.S. lamb consumption (Table 7). Despite having a population only 7% that of the United States, Australia annually consumes about twice the volume of lamb consumed in the U.S. The consequence is that per capita consumption in Australia is about 20 times that in the U.S. on a retail equivalent basis. Other major lamb consuming countries include New

[5] All data for 1996 on a retail weight equivalent basis.

Figure 8. United States lamb consumption (1975 through 1996).

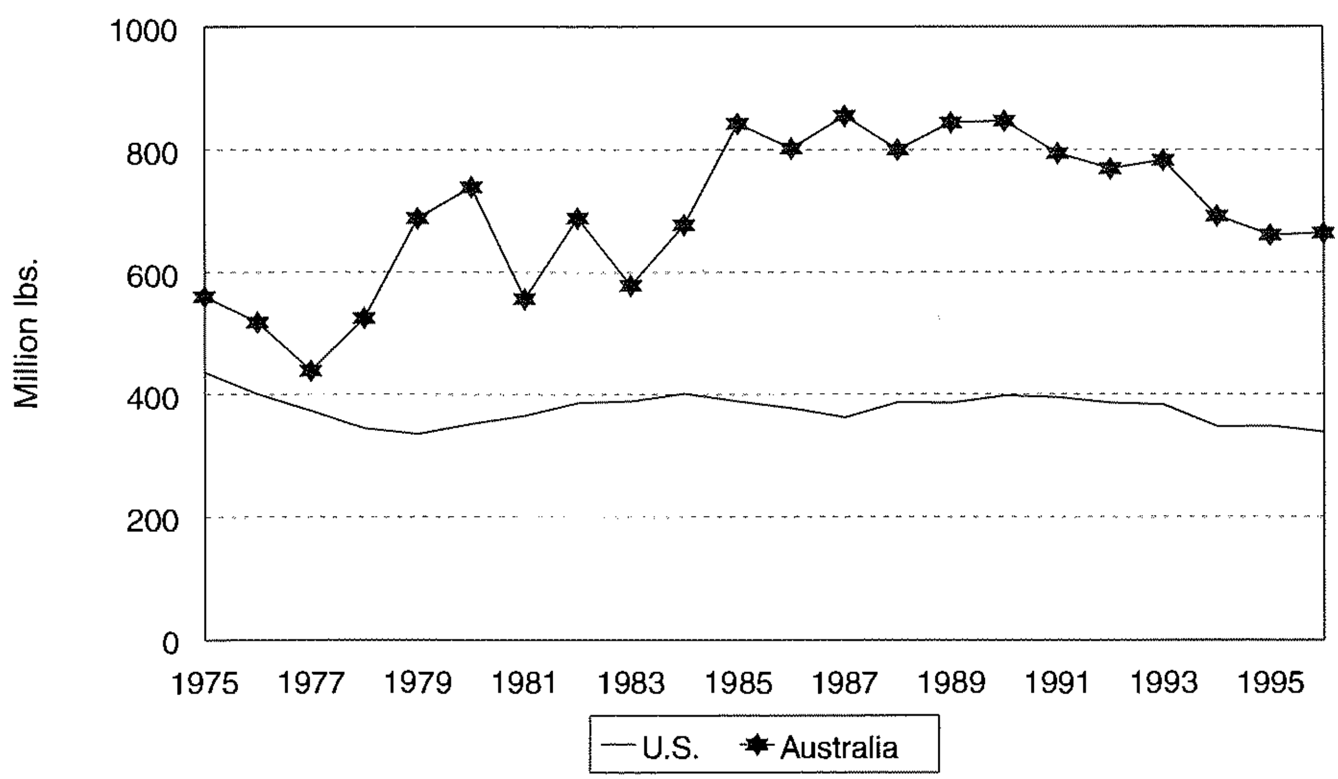


Zealand and Greece with per capita consumption (retail weight) of about 26 and 13 pounds, respectively (Table 7). Per capita lamb consumption in Ireland, the United Kingdom and Turkey is about 8.2, 5.3 and 5.5 pounds, respectively. France and Spain each consume about 5 to 6 pounds per capita annually. Per capita consumption levels in Japan are comparable to those in the U.S.

The 1987-88 Nationwide Food Consumption Survey (NFCS) conducted by the Human Nutrition Information Service (HNIS) of the U.S. Department of Agriculture (USDA), provides a wide range of demographic and other information to build a profile of current lamb consumers. The NFCS provides extensive information on U.S. food consumption behavior and is often used to assess the impact of policies relating to food production and marketing, food safety, food assistance, and nutrition education. The survey results provide valuable insights into the characteristics of lamb consumption across various key demographic factors relative to other meats:

- ***Geographic location:*** Lamb, fish/seafood and beef expenditures are greater in the Northeast and the West relative to the Midwest and the South. Poultry expenditures are the most in the Northeast and the least in the Midwest. Expenditures on pork are virtually uniform in the Northeast, Midwest and South but are noticeably smaller in the West compared to the other regions.
- ***Seasonality:*** Lamb and poultry expenditures are greater in the fall relative to the other seasons whereas the opposite is the case for beef. Fish and seafood expenditures are greater in the winter and spring relative to the summer and the fall while the reverse holds with respect to pork expenditures.
- ***Income quintile:*** In all cases except lamb, per person expenditures for meat products generally increase with increases in income suggesting that income is less of a factor affecting expenditures on lamb than is the case for other meats.
- ***Race:*** Whites spend more on beef than blacks and other racial groups. On the other hand, blacks spend more on pork and poultry than whites and other racial groups. Other racial groups spend more on fish and seafood than whites and blacks. Finally, whites expend less on lamb and miscellaneous meats than blacks and other racial groups.
- ***Age:*** Expenditures for lamb are greatest in the 55 to 64 and 65 and older age groups relative to other groups. The same is true for poultry. Expenditures on beef, pork and fish/seafood made by the elderly decline compared to those made by individuals in the 45 to 54 and 55 to 64 age groups.
- ***Urbanization:*** Expenditures for lamb and other meats except pork by urban households are greater than those by rural households suggesting a strong urban base of expenditures on most meat products, including lamb.

Figure 9. Lamb consumption in the United States and Australia (1975 through 1996).



Lamb Market Structure and Implications for Price Discovery

The particular way in which a market is organized determines its structure[6] and heavily influences the competitive conduct of the firms in the industry which, in turn, dictates how prices in the industry are established and behave. The ways in which prices are determined under different types of market behavior usually differ widely. If the structure of an industry, and therefore competitive behavior, differ markedly at different levels in the industry, prices at each industry level will likely be determined in very different ways. Consequently, to gain insight into the particular process(es) by which prices are determined in the lamb industry, the structural characteristics and the associated competitive behavior at each level in the lamb industry must be understood.

Figure 10 illustrates the structure of the lamb industry and is a simplified version of Figure 1 which illustrated lamb market distribution channels. In Figure 10, however, the "flows" between each level now represent the interaction of the particular market structures at each level (i.e., the flow of market power, or the ability to influence market behavior, from sellers to buyers and from buyers to sellers). The arrows between market levels moving from left to right indicate the way in which sellers are organized as they interact with buyers at the next level up in the industry. Similarly, the arrows flowing from right to left between market levels indicate how buyers are organized as they interact with sellers at the next level down in the industry. The number of participants in the market decline and the market structure moves further away from perfect competition as one moves from either end of the system toward the middle. The implication, of course, is that the forces of supply and demand tend to be less and less important in determining lamb prices the further toward the middle of the system one moves.

Producers, the original suppliers of the raw ingredient in the industry, are so numerous that the actions of individual producers have little individual effect on the market. Their collective, independent actions constitute the market supply of feeder lambs and sheep. Producers sell a relatively homogeneous product (live sheep and lambs) and have a fairly good knowledge of market opportunities and alternative prices. Because there are some differences in lamb and sheep characteristics and because they do not have perfect knowledge of all possible market conditions, producers operate within a *near perfect* competition market structure. Lamb producers are basically price-takers and individually powerless to affect the prices at which they sell their sheep and lambs. The consequence is that producers must accept the price outcomes from the interactions of groups with more market power further up the line in the system.

A relatively few number of **commercial feeders** purchase feeder lambs from producers and account for a large percentage of the sheep and lambs fed. Consequently, feeders operate as *oligopsonists* in their interactions with producers who operate more as price-takers in a near perfect competitive environment (Figure 10). The prices feeders pay for feeder lambs, however, largely reflect the prices they receive for slaughter lambs as they behave as oligopolists facing oligopsonistic **packers** on the selling side in a *bilateral oligopoly* (oligopoly

Table 6. Average annual United States per capita consumption of red meat and poultry products (1970 through 1996, selected years; retail weight equivalent).[a]

	Year, pound per capita			
Meat	**1970-72**	**1980-82**	**1990-92**	**1996**
Red meats	146.8	133.9	120.2	119.1
Beef	84.8	77.3	66.7	67.7
Veal	2.1	1.5	1.0	1.2
Pork	57.1	53.7	51.1	49.1
Lamb	2.9	1.4	1.4	1.1
Poultry	49.5	60.4	82.2	90.1
Chicken	41.0	49.9	64.4	71.6
Turkey	8.5	10.5	17.8	18.5

[a] Source: LMIC, 1997.

Table 7. Per capita lamb, mutton and goat meat consumption in selected countries (1975 through 1996, selected years; retail weight equivalent).[a]

	Year, pound per capita			
Country	**1975-79**	**1980-84**	**1985-89**	**1992-96**
United States	1.1	1.0	1.1	0.6
Greece	13.9	13.7	14.2	12.7
Ireland	9.6	7.5	9.5	8.2
United Kingdom	7.6	7.2	6.3	5.3
France	3.7	4.1	5.2	4.8
Spain	4.0	3.7	6.2	5.8
Mexico	0.8	0.8	1.6	1.5
Turkey	8.2	6.6	6.1	5.5
Japan	2.4	1.4	0.6	0.6
Australia	20.4	19.9	16.6	16.3
New Zealand	32.9	33.7	32.5	25.6

[a] Source: USDA, 1997b.

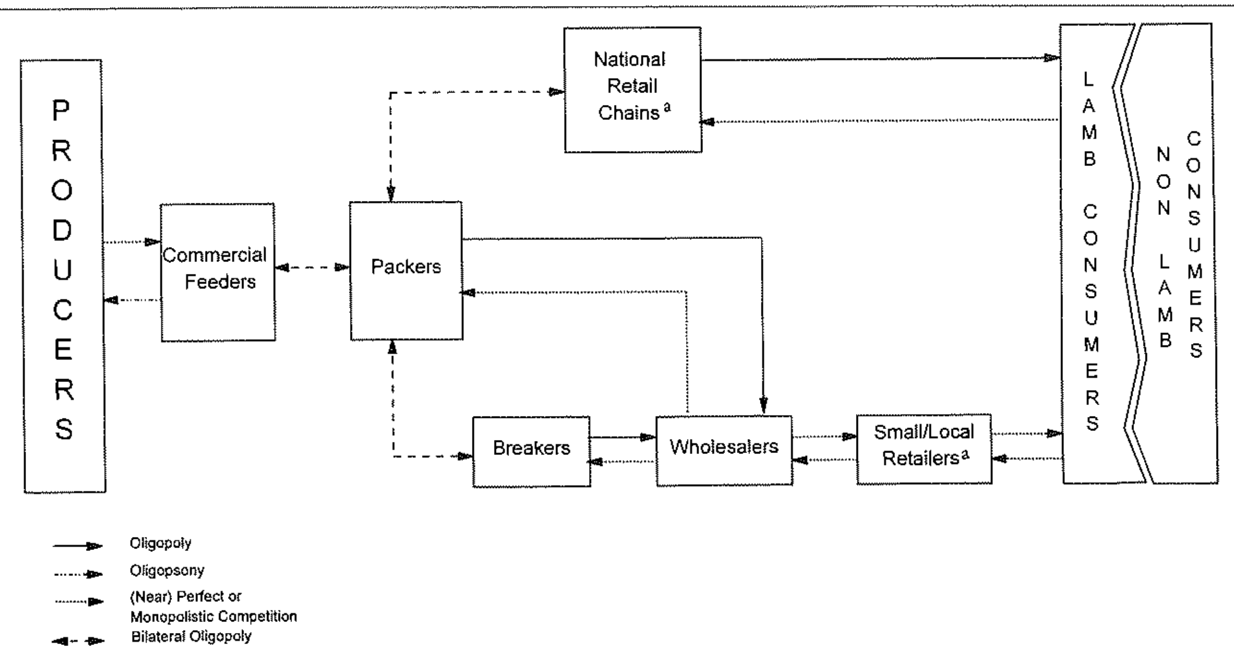
on the buying and the selling side of a market). In a bilateral oligopoly, the forces of supply and demand are not the primary determinants of the price level but rather relative bargaining power and similar factors. To be efficient, feeders must operate on a fairly large scale and operate at near full capacity. Although feeders have some flexibility in bargaining on price, most large feeders sell on a double dressed weight carcass basis. As a consequence, packers set prices with little or no bargaining with feeders involved.

Feeders seem to be satisfied with this process, likely because bargaining with packers is not a realistic alternative for at least two reasons. First, there are relatively fewer packers than feeders, particularly in regions of high concentration of large commercial feeders such as Colorado. Consequently, most feeders have few alternative buyers to whom they might sell their animals if they do not like the prices offered by their current buyer. Second, real bargaining power by sellers implies an ability to withhold supply from the market until buyers are willing to pay the price demanded. In fact, once fed lambs reach slaughter weights, feeders must move them to market within a relatively short period of time or end up with heavier and heavier lambs that are worth less and less every day. Contracting to supply a packer or packers with a minimum number of slaughter lambs and allowing the packers to dictate the price is a rational, less risky alternative. This is not to say that there is no bargaining at all between packers and feeders because at different times of the year various packers may be more or less willing to bargain with feeders on price. More likely, however, the bargaining involves the percentage of the packers' projected slaughter lamb requirements to be supplied by different feeders and the particular formula or process through which packers determine the prices they pay. The consequence is that feeders act like price takers in dealing with packers to a large extent and price the feeder lambs they purchase according to the prices they receive for slaughter lambs after deducting their costs, including a reasonable profit.

Packers operate within a market structure similar to that of feeders in that they behave as oligopsonists in buying slaughter lambs and as oligopolists facing oligopsonists in attempting to sell processed lamb. They operate on the output side within a complicated ***double bilateral oligopoly***, facing the oligopsonistic behavior of both central procurement operations of large **retail chainstores**, large **food service buyers** and large **breakers** who service the needs of many small wholesale and retail operations in specific geographical areas of relatively high demand (Figure 10). Again, the price level set in this environment is indeterminate and factors other than supply and demand are often the primary forces dictating price and quantity decisions.

Packers are at a distinct disadvantage in bargaining on price with the large retailers or the few large food service buyers that centrally buy in volume for the reasons discussed previously. First, packers must operate at as close to full capacity as possible to be efficient and must move their processed lamb soon after slaughter and

Figure 10. Lamb industry market structure.



[a] "Retailer" as used here includes both food stores and food service.

processing or face spoilage losses. The large volume retailers[7] recognize the situation of packers and can use it against them, threatening not to purchase, to purchase significantly less than otherwise or even to purchase a larger percentage through breakers if the packers do not accept the retailers' price terms. As noted earlier, the large retailers routinely purchase a significant portion of their lamb supplies directly from breakers. As a consequence, packers have little latitude in bargaining with the oligopsonistic retailers.

Also, retailers handle thousands of food items per store (or per food service operation) and normally are more interested in competition with rival retailers across many commodities than in bargaining with sellers of each individual item. Lamb, in particular, is a perishable commodity and a minor item among the thousands carried by the retailers and consequently contributes little to overall profitability. Lamb comprises no more than 1 to 2% of the meat case of most retailers and is even less important when considering the thousands of items offered by retailers to consumers. Consequently, retailers can realistically make "take-it-or-leave-it" offers to packers and threaten to leave them holding a great deal of inventory if the asking price is not right. The real price determining behavior of retailers occurs as an interaction among the large oligopolistic retailers rather than in retailer-to-packer interactions.

A decision by a major volume-buying retailer to cut lamb offerings from 2 to 1% of the meat case would have little impact on the profits of the retailer but would have a tremendous impact on the sales volume of the supplying packer. In other words, whether or not a retailer has lamb in the meat case to sell is much less of a problem for retailers (for whom lamb is a minor product among the various product lines they carry) than for packers, for whom lamb is often either the only product or the major product of their business. Consequently, packers are at a disadvantage in the price-setting process.

Interestingly, lamb tends to suffer from this process relative to other meats like beef because of the oligopolistic interaction of retailers. Because the retail food business is very much oligopolies of a few large retail food store chains or food service chains with a monopolistic competition fringe of smaller local retailers, pricing strategy is not the primary means of competition. Price is generally set through some process such as price leadership and then left at that level with minor adjustments over time for inflation, etc. Indeed, the retail price of lamb tends to vary little from week to week and month to month (Williams et al., 1991). Rather, retailers attempt to differentiate their stores by creating various "images" (i.e., low price, high quality, good selection, fresh products, combinations thereof) that attempt to appeal to various groups of consumers. In doing so, retailers focus on various "image-creating" products. By advertising the freshness, value, selection, quality or other aspects of such image products, retailers create the desired images for their stores. Beef, for example, is often used as an image-creating product. Retailers must be more concerned about the price, availability and quality of such image products than they are for minor offerings and therefore are more vulnerable to the negotiating tactics of image product suppliers.

The dominant bargaining power of retailers is evident in the "offer and acceptance" or "bid" system of lamb procurement that is prevalent in most areas where large volume lamb purchases by food retailers are important. In this system, suppliers make offers to retailers in which they specify quantities and prices. At one time, retailers shopped the meat coolers of packers and made offers which the packers either accepted or rejected. The acceptance or rejection was immediate (Williams, 1966). Some bargaining, therefore, was a normal part of the process. In the bid system, however, the retailer receives all offers from alternative suppliers (including breakers) before any offer is accepted. The retailer often refuses to bargain or to give the bidders an opportunity to revise their bids; he simply accepts or rejects. Williams (1966) indicates that the bid system provides retailers with "maximum opportunity to exploit the positions" of suppliers that may be burdened with large lamb supplies and of those who financially cannot afford rejection.

Packers are in a more advantageous bargaining position when it comes to breakers because lamb tends to be the only or the major product handled by breakers. The goodwill of the packer is therefore essential to the business of the breaker. At the same time, the breaker plays a role in carrying inventory for many small wholesalers and retailers. The breaker, like the packer, must move the inventory he carries within a relatively short period of time. The level at which price is set between packers and breakers is indeterminate as in any bilateral oligopoly but likely depends much more on the bargaining process than is the case with the packer-to-retailer interaction.

On the output side, the large **retail food store or food service chains** operate nationally as *oligopolists* with a fringe of monopolistic competitors in various local areas facing a large number of consumers who purchase lamb as near perfect competitors. As a consequence, supply and demand again mean little to the pricing decision. That is, lamb consumer preferences are only slowly if at all reflected in the pricing decision. Because the major retail lamb competitors operate as a food retailing oligopoly, retail price competition is generally avoided. Once the retail price is set through the price leadership of some dominant retailer or group of retailers in the oligopoly or some other process, the price of lamb tends to remain quite stable, varying little at retail and only adjusted upward with a lag for inflation and other factors. To be sure, retailers frequently run price specials on lamb. These, however, tend to be related to efforts to move seasonally large supplies of lamb. The retailers responding to the TAMRC survey indicated overwhelmingly that price is

[7] To simplify the discussion, the term "retailer" will be used to refer to both food store and food service operations.

seldom used as a means to promote sustained growth in lamb sales.

Also, any retail profit realized on lamb as the result of lower costs may not be passed on to consumers for at least two reasons. First, because lamb prices tend to be fairly stable at retail, increases in cost are not often translated immediately into higher retail prices. Consequently, gains from declines in the cost of lamb to retailers can be used to offset the losses from periods of increasing cost. Second, profits accruing to lamb can often be more efficiently used by retailers to help lower the prices of their "image products," such as produce or beef, that draw in customers. Passing on declines in the cost of lamb to lamb consumers will draw in relatively fewer total customers than a similar decline in the prices of image products.

Breakers operate within their own realm as *oligopolists* in their interactions with lamb wholesalers of various types (or retailers, even though this relationship is not highlighted in Figure 10). The prices charged by breakers also change little from week to week and month to month as indicated in the TAMRC survey responses of all the wholesalers and retailers that purchase a large portion of their lamb supplies from breakers. Because breakers operate as oligopolists, competition among breakers is not primarily price-based but rather service- and convenience-based (Williams et al., 1991). That is, breakers differentiate the products they offer to buyers through the service and convenience value they add. Because the basic lamb products offered by breakers are not highly differentiated among the different breakers, they resort to gaining market share by providing better service, more reliability, larger offering of products fabricated to individual user specifications, greater convenience, etc. This is also the way in which breakers have attempted to differentiate themselves from packers.

The oligopolistic price-setting power of breakers, however, is much less than many in the lamb industry have assumed, particularly in recent years, for at least two reasons. First, packers have revolutionized the lamb distribution system by moving rapidly away from selling mainly carcasses to selling boxed lamb. Much of the initial breaking and boxing of primals and subprimals is now being done by the packer. As noted earlier, the percentage of the initial breaking done by packers has jumped from about 30% in 1990 to about 70% now. Breakers are responding by doing more fabrication of lamb and marketing directly to smaller, local retail operations in many areas in competition with their own wholesale customers. The move by packers into boxed lamb has enabled them not only to take over some of the functions traditionally performed by breakers but also to better service the medium volume lamb wholesale and retail customers of breakers, who prefer to purchase only certain cuts rather than full carcasses. Second, because breakers tend to serve only certain regions of the country, their oligopoly power is also quite regional in nature. Prices charged by breakers to wholesale and retail buyers tend to be set through price markup behavior as indicated in breakers' responses to the TAMRC survey. Consequently, national price leadership of the large chain retailers is a major influence in the price determining behavior among breakers in local geographic areas.

Beyond breakers in the lamb industry structure are many **small wholesalers** and **retailers** who act in a *near perfect* or *monopolistically competitive* environment. They are price takers, therefore, both in buying and selling lamb. They set the prices of the lamb they sell on a "cost-plus-markup" basis. The prices thus reflect the price setting behavior at the packer-large retailer-breaker levels. Nevertheless, because the small retailers operate in a monopolistic competition framework, price tends to vary more around the "industry" price because price strategy is a viable means of competition under this market structure. This is particularly true among specialty meat stores and butcher shops.

At the front end of the system are **consumers**, the ultimate users of the lamb product that is fed, processed, fabricated and prepared for retail sale. Consumers are numerous enough that they also become price takers in a *near perfect competition* environment. They face the oligopolistic behavior of the large national retail chains and the more price-competitive behavior of local retailers. As discussed earlier, however, only about 24% of retail food consumers can be considered to be even occasional lamb consumers. Also, most lamb consumers are older, belong to certain ethnic groups and traditionally consume lamb in relation to certain religious observances. The consequence is that current lamb consumers are fairly insensitive to price and income changes. In other words, the consumption of lamb by current consumers is fairly steady and not highly affected by price or income changes. Certainly price specials on lamb induce these consumers to purchase more lamb. However, they tend to stock up on lamb rather than expand total use as a result of price specials. Consequently, following price specials, lamb purchases tend to drop off to a level below that purchased prior to the price special before returning to more normal levels. In the end, little more lamb tends to be sold on average. The price specials serve more to move inventory holding from sellers to consumers than to create additional use of lamb.

The insensitivity of current lamb consumers to price changes has important implications for pricing strategy by retailers. Because a decline in the price of lamb at retail tends to result in few additional sales *on average*, retailers lose revenue by lowering price since the increase in sales is insufficient to offset the decline in price. In contrast, raising the price at every opportunity brings in more revenue because the decline in sales will be small as a result. Thus, movements of price at retail tend to be asymmetric, moving up much easier and more often than down.

Conclusions and Implications for Value Communication in the Lamb Industry

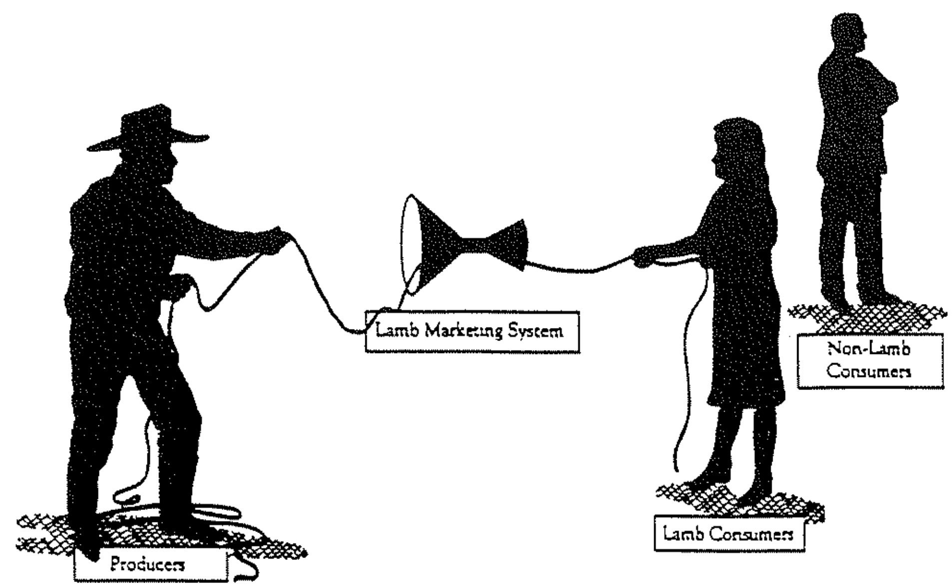
In a perfectly competitive industry, the value of products offered by sellers as perceived by buyers is communicated from consumers to producers through the price signals generated by the interaction of supply and demand. The individual preferences of many small consumers, taken together, create a market demand which confronts the aggregate market supply made up of the individual offerings of many small producers. The result of the confrontation is a market price which reflects both the preferences of consumers and the decisions of producers. Increased consumer preference for a certain product with certain quality characteristics is reflected in a higher price for that product, signaling an opportunity for producers to expand production of the product with the desired characteristics. By the same token, an increase in the availability of a product relative to consumer preferences for it would be reflected in a lower price, signaling producers to curtail production. If there are no obstructions in the system, producers will quickly feel the pull or push of consumers and vice versa as indicated by changes in market price. There are few agricultural markets, however, in which the producers of the raw product interact directly with final consumers. Many groups now come between producers and sellers and transform or otherwise add value to the raw commodity offered by producers before it finally reaches the consumer's plate. One of the consequences is that a small and declining portion of the retail food dollar goes to producers. Even so, the interaction of supply and demand in a competitive environment at each level in the industry would mean that the price signals of consumers would still be transmitted down through the system to producers.

Unfortunately, the different market structures, conducts, and price discovery processes at each level of the lamb industry create some difficulty for value preferences to migrate from consumers to producers. This situation is best illustrated in Figure 11, which simplifies and combines the lamb market distribution system (as represented in Figure 1) and the lamb industry market structure (as represented in Figure 10). The man at the left represents the large number of sheep and lamb producers attempting to push their product through the marketing system as if pushing on a rope. On the other end are lamb consumers represented by a small person pulling on the rope at the other end. Behind her is a large but disinterested individual representing the vast majority of consumers who do not purchase lamb.

Between the producer and the consumer is the lamb marketing system under its current market structure. The middle of the system is narrow and obstructed. The oligopoly, oligopsony and bilateral oligopoly behavior – particularly of packers, large retailers and breakers – means that competition at those points in the system is largely based on non-price factors, many of which have more to do with bargaining power and personal relationships than with the quality or value of the product. The result is that price is no longer an adequate signal of consumer preferences. As a consequence, producers and consumers communicate only with great difficulty and usually with great lags in time.

Producers thus find it difficult if not impossible to know what consumers want in attempting to push the rope (sheep and lambs) towards consumers through the narrow obstructed system. Likewise, consumers on the other end find it difficult to pull the rope according to their preferences for quality and value through the narrow obstructed system. At the same time, the small number of consumers pulling puts only moderate tension on the rope, a force inadequate to pull the rope through the system and take up the slack at the producer end. As a result, producers have difficulty

Figure 11. A simplified representation of the current lamb market system.



feeling the market signals of consumers as they push and pull on the rope. Consumers also find it difficult to feel the signals of producers as they push and pull on the rope from the other end.

Figure 11 suggests that only three things can be done to remedy the problem and insure that the signals of lamb consumers pass more easily through to lamb producers and vice versa: 1) remove the obstacles in the marketing system; 2) generate more pull from the consumer end; and/or 3) encourage cooperative efforts among producers to strengthen the pull from their end. Historically, the first two have received more attention than the third. The meat industry has mounted periodic attempts to attack the oligopoly obstacles in the system through legal means. The idea has been that breaking up the few large packers or retailers into smaller units would create a more price competitive environment. These efforts have met with varying degrees of success. The issues of economies of size[8] and other barriers have proven difficult to deal with in this process. Breaking up packers into many smaller capacity firms could significantly increase the slaughter cost per head, making it difficult for many of the smaller packers to operate and ultimately reducing total national lamb slaughter capacity.

Attempts have also been mounted to strengthen the pull on the rope from the consumer end. The national checkoff programs of the beef and pork industries, for example, have generated significant funds that are used to promote consumption of their products. Unfortunately, a proposal for a similar program for lamb was defeated in a recent producer referendum. The appealing aspect of efforts to enhance consumer pull is that success in augmenting the consumption of current consumers and in attracting new consumers also tends to weaken the obstacles in the marketing system (as illustrated in Figure 12). With more consumers purchasing lamb, the volume of lamb moving through the system increases, providing increased profit opportunities at each level in the industry. Without a lamb checkoff or similar program to generate promotion funds, however, this option for helping resolve problems in the U.S. lamb industry is virtually unavailable.

With less than satisfactory results both in generating promotion funds and in achieving change through legal and legislative means, producers have turned increasingly to cooperative efforts to improve their competitive market power. For example, despite the failure of a recent cooperative effort in Texas (American Lamb Producers, Inc.), Texas lamb producers are planning a new cooperative venture (Rancher's Lamb) to include a new 400,000 head per year kill facility and some vertical integration with lamb feeders. Such efforts may prove to be the key to improving the level of price competition, enhancing the communication of value from consumers to producers and rescuing the U.S. lamb industry from decades of steady decline.

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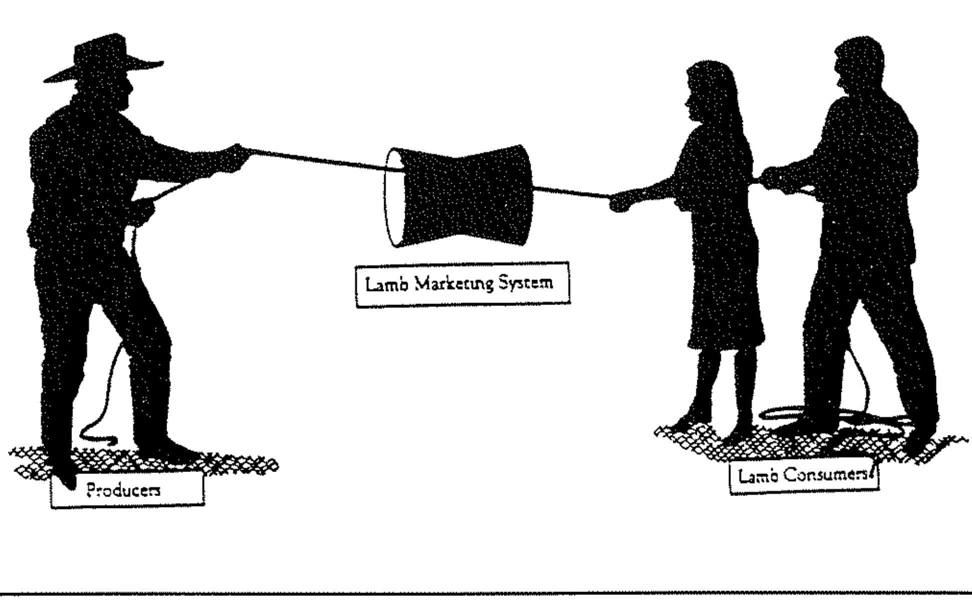
[8] "Economy of size" refers to the reduction in the cost of production from an increase in the volume of production. Thus, the larger the slaughter capacity of a lamb packer, the lower the slaughter cost per head when operating at full capacity.

Figure 12. A change in the current lamb market system caused by increased demand.



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Slaughter Lamb Pricing Issues, Evidence and Future Needs

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Summary

High (low) slaughter lamb prices result from supplies which are small (large) relative to lamb demand conditions. Supplies may be high (low) due to cyclical or seasonal production factors. Widely varying prices, both within and between weeks and both above and below the market price level, result from many factors directly affecting price discovery. Examples include: 1) quality and location of slaughter lambs; 2) buyer competition and marketing method; and 3) availability and accuracy of market information. Two different but interrelated concepts which need to be understood when discussing prices and pricing issues are price determination and price discovery. This article reviews price determination and price discovery concepts and evidence, then addresses some future needs related to lamb prices and pricing.

Key words: pricing, price discovery, slaughter lambs.

Price Determination and Price Discovery Concepts

Price determination is the interaction of the broad forces of supply and demand which determine the market price *level* (Tomek and Robinson 1981). In a typical textbook diagram for price determination, a supply curve and a demand curve intersect to determine the general price level. For slaughter lambs, supply determinants or factors affecting the quantity of lamb produced include input prices (such as feeder lamb and grain prices) and price of outputs produced from those inputs (such as slaughter lambs and pelts) along with other factors (such as technology or genetics). Broad demand forces or factors affecting the amount of lamb consumed include the price of products produced from slaughter lambs (primarily lamb), price of competing products (such as beef and veal), consumer income and consumer tastes and preferences.

Price discovery is the process of buyers and sellers arriving at a transaction price for a given quality and quantity of a product at a given time and place (Thomsen and Foote, 1952). Price discovery involves several interrelated concepts, among them: 1) market structure (number, size, location, competitiveness of buyers, sellers); 2) market behavior (buyer procurement, pricing methods); and 3) market information and price reporting (amount, timeliness, reliability of information).

Price discovery begins with the market price level. Because buyers and sellers discover prices on the basis of uncertain expectations, transaction prices fluctuate around that market price level. We never know exactly the shape and location of the demand and supply curves. Therefore, we can only estimate demand and supply. Those estimated supply and demand curves intersect at a range of quantities and prices, meaning that discovered prices fluctuate above and below the general or market price level. This fluctuation is attributable to the quantity and quality of the commodity brought to market, the time and place of the transaction and the number of potential buyers and sellers present. Other factors, in the case of slaughter lamb prices, are the amount and type of public market information available, forward purchased supplies of slaughter lambs and packer concentration.

Price Determination and Related Concepts

Demand for lamb begins with the consumer. Little will be said about the demand for lamb since it is covered in another article in this Special Issue (pages 106-120, Purcell). However, we need to begin at the retail demand level and tie it to farm level production, thus entailing a discussion of marketing margins. We can modify the discussion of marketing margins by Tomek and

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Robinson (1981). The demand curve for lamb at the retail level is called the primary demand and the supply curve for lambs at the farm level is the primary supply. The demand for feeder, slaughter and wholesale lambs is derived from the retail or consumer demand for lamb and is called the derived demand. The amount of lamb reaching consumers depends on the size of the lamb crop and the weight of lambs slaughtered. Thus, supply at retail is derived from the primary supply and is called the "derived supply." The intersection of the primary demand and derived supply curves determine the general or market price level for retail lamb, while the intersection of the derived demand and primary supply curves determines the general or market price level for slaughter lambs. The difference between the retail price and slaughter lamb price is the marketing margin or cost of processing, wholesaling and retailing lamb.

Producers, and sometimes consumers, often raise several questions regarding the movement and difference between farm level and retail level prices. Do retail lamb prices change as quickly as slaughter lamb prices? Do retail prices increase more quickly than they decline? First, we must understand that market costs (i.e., the farm-to-retail price spreads) are necessary. Consumers do not eat live lambs, most do not live where live lambs are raised and most want lamb at times other than when lamb feeders decide to have lambs slaughtered. Therefore, several processes are necessary in converting live lambs to consumer-ready lamb products. Slaughter and processing add *form* value to slaughter lambs, transforming live lambs into consumer cuts. Packers, breakers and wholesalers add *time* value to lamb by storing lamb and distributing products when consumers demand them. Transportation adds *place* value to slaughter lambs, by moving slaughter lambs from feedlots to processing plants and then to wholesale and retail points where consumers purchase lamb. All of these functions add costs to the initial cost of producing slaughter lambs and comprise the farm-to-retail price spread or marketing margin.

Price spreads are often divided into farm-to-wholesale and wholesale-to-retail. These can be thought of as slaughter lambs-to-carcass and carcass-to-retail. In one recent study examining price spreads for lamb (Texas A&M Market Research Center [TAMRC] Lamb Study Team, 1991), researchers noted that retail lamb prices tended to remain relatively steady over the 1978-to-1990 period. Therefore, increases in marketing costs over time tend to place downward pressure on slaughter lamb prices. Researchers reported that real (adjusted for inflation) as well as nominal (unadjusted) slaughter-to-retail marketing margins for lamb increased over the study period. While their work has not been updated beyond 1990, their findings have not likely changed much to date.

The two components of the slaughter-to-retail price spread differed (TAMRC Lamb Study Team, 1991). The real slaughter-to-wholesale margin has declined, from \$22/cwt in 1978 to about \$12/cwt in 1990. This decline suggests that the lamb packing industry has become more efficient over the data period. Plants have increased in size and have capitalized on economies of size to reduce operating costs. Results of this trend are evident: consolidation of packing firms, declines in plant numbers and increased packer concentration over the same period.

The second component, the wholesale-to-retail margin, increased sharply both in nominal and real terms (TAMRC Lamb Study Team, 1991). The real wholesale-to-retail component increased from about \$19/cwt in 1978 to nearly \$80/cwt in 1990. The reasons for the rapid increase are not well understood. The real wholesale-to-retail component for pork remained relatively constant during the same period and declined slightly for beef. One possible explanation relates to the size of the lamb industry. Many of the marketing institutions and cost operations are the same for lamb as other meats. However, the lamb industry is smaller and thus cannot capitalize as effectively on cost economies or efficiencies associated with large volume operations. Sometimes, increasing marketing costs can be passed on to consumers. However, not when demand is stagnant or declining as Purcell (1989 and 1995) argues has occurred for lamb. Therefore, increased marketing costs are borne predominantly by sheep producers. Over time, this means lower prices for slaughter and feeder lambs, smaller profit margins and declining numbers of sheep producers as they exit the industry. Real slaughter lamb prices fell from about \$110/cwt to about \$35/cwt over the 1978-to-1990 period.

An econometric model attempted to explain the factors contributing to lamb price spreads using bimonthly data for the 1978-to-1990 period (TAMRC Lamb Study Team, 1991). Models estimated included one for the farm-to-retail marketing margin as well as models for each component (slaughter-to-wholesale, wholesale-to-retail). For each respective model, price spread increases were explained by: 1) increases in lamb prices; 2) the interaction of lamb prices and quantity of lamb; and 3) an index of marketing costs. The overall slaughter-to-retail price spread and the wholesale-to-retail component increased as packer concentration increased but not the slaughter-to-wholesale component. A trend variable was positive in all models, suggesting that a positive change in technology may have occurred during this time, and it may be the trend toward further processing lamb into boxed lamb primal and subprimal cuts. Seasonality was found in each model as well, even more so in the overall slaughter-to-retail price spread and the wholesale-to-retail component than in the slaughter-to-wholesale component.

Slaughter lamb prices are derived from retail lamb prices in theory and as described above. However, economists who have studied the dynamics of retail, wholesale and farm level prices find that empirical estimates suggest two alternatives are possible. Work by Owen et al. (1991) for beef suggested a derived movement of prices from retail to the fed cattle level. Boyd and Brorsen (1985) and others argue that most price changes originate at the farm level with supply changes, thus suggesting that markup pricing is more common than derived demand pricing.

Jones and Purcell (1993) examined weekly data for the period from January of 1987 to November of 1988 using a vector autoregressive model (VAR). Specifically, they tested price transmission theories in the lamb industry; derived demand versus markup pricing. Their results suggested that prices follow a markup pricing framework but with longer time lags than have been found for beef and pork (Miller, 1979; Boyd and Brorsen, 1985; Schroeder and Hayenga, 1987). Unlike beef and pork, Jones and Purcell (1993) found evidence of a bidirectional flow of causality, both from slaughter lamb prices to retail lamb prices and the reverse. The strongest evidence was that wholesale and retail prices tend to adjust to live level price changes with a lag of several weeks. Retail prices respond in four to five weeks.

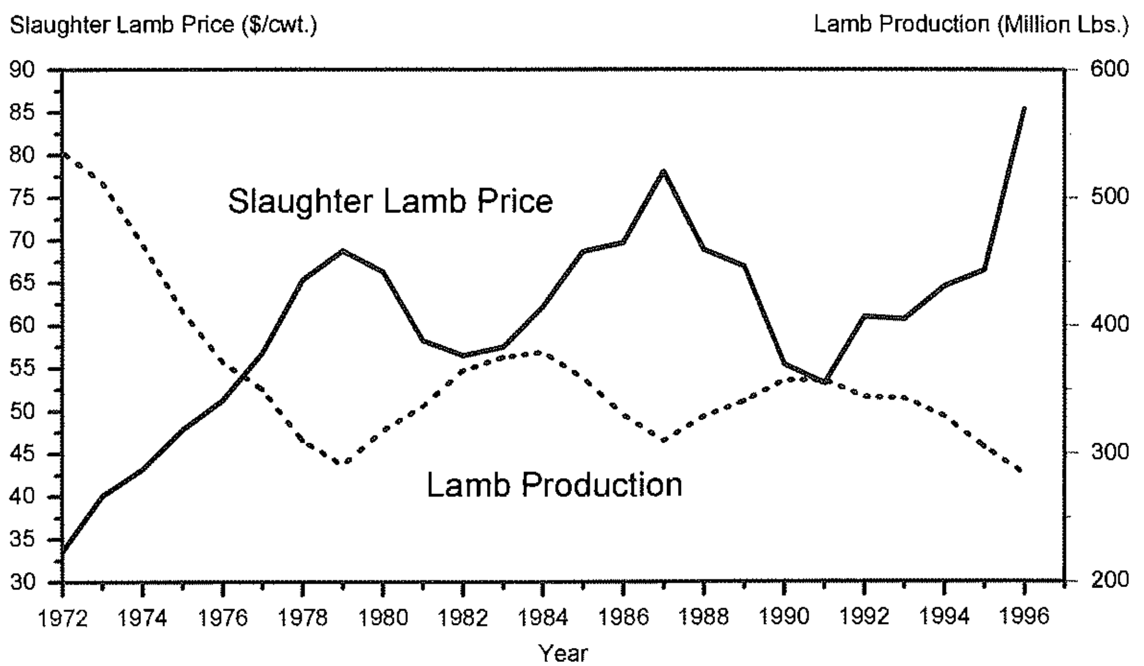
Long time lags and incomplete price transmission from one level to another suggest slow and inefficient price discovery in the lamb marketing system (Jones and Purcell, 1993). Price signals are not clearly and completely passed from the consumer or retail level to the lamb feeding or slaughter lamb level. While not studied, lamb signals may also not be transmitted clearly and completely to the production or feeder lamb level from lamb feeding or slaughter lamb level.

Jones and Purcell (1993) argue that lamb supplies influence prices more than consumer demand. This supply influence on prices can be illustrated in another way. Figure 1 shows annual domestic lamb production for 1972 to 1996 graphed against annual average slaughter lamb prices at San Angelo, TX, for the same period. Lamb production is read off the right axis and slaughter lamb prices off the left axis. Note the almost mirror image effect of the two lines: when lamb production decreases, slaughter lamb prices typically increase; and when lamb production increases, slaughter lamb prices typically decrease. Thus, slaughter lamb prices are determined in large part by lamb supplies or domestic lamb production. As Jones and Purcell (1993) found, there is some influence from consumer demand changes. But, lamb supplies are the dominant determinant, as shown in Figure 1.

Lamb production in Figure 1 is quite variable over time and appears to have a cyclic nature. Livestock production and price cycles have concerned economists for many years, especially for cattle and hogs (Franzmann, 1971 and 1979). Cycles are caused by an interaction of biological and economic factors. Typically, when livestock prices are high, producers retain breeding stock which further reduces supplies and increases prices. Then, there is a biological lag between retaining new breeding stock and the production of additional livestock for slaughter. Eventually, increased slaughter livestock supplies cause prices to decline. In response, producers liquidate breeding stock, further increasing meat supplies and contributing to further downward pressure on prices. After the appropriate time lag, production again is reduced and prices increase, thereby stimulating the next cycle.

VanTassell and Whipple (1994) indicate that little attention has been paid

Figure 1. San Angelo, TX, slaughter lamb prices and United States commercial lamb production data.



to production and price cycles in the U.S. sheep industry. They use harmonic regression and minimization of Akaike's information criterion (MIAC) to study production and price cycles in the sheep industry from 1924 to 1993. Annual sheep inventory data was used to estimated production cycles and monthly slaughter lamb prices were used to estimate price cycles. Cyclical and seasonal patterns were found for lamb prices and cyclical patterns were found for sheep production.

Results suggest that the nature of sheep cycles has been statistically altered over time, most notably following World War II and again in the late 1960s and early 1970s. The authors identify several potential explanations, relating both to lamb and wool. For example, they suggest that lamb demand was adversely affected by eating experiences of military personnel during World War II and wool demand was adversely affected by increased synthetic fiber competition in the 1960s. In general, VanTassell and Whipple (1994) found that cycle length has shortened over time, both for inventories and prices. The more recent sheep inventory cycle was about 10 years in length, while it was 9 years for slaughter lamb prices. The amplitude of the sheep inventory cycle has dampened over time but has increased for the slaughter lamb price cycle.

These cycles have persisted even with the sharp decline in sheep numbers since World War II. Production and price cycles appear to still persist (Figure 1), but a question remains as to whether cycles will continue following recent liquidation in sheep numbers coinciding with phase-out of the National Wool Act. The subsequent sharp increase in slaughter lamb prices would normally evoke an increase in breeding stock retention (i.e., a rebuilding of the sheep inventory) leading in turn to further increases in slaughter lamb prices and the beginning (or continuation) of a sheep inventory and slaughter lamb price cycle.

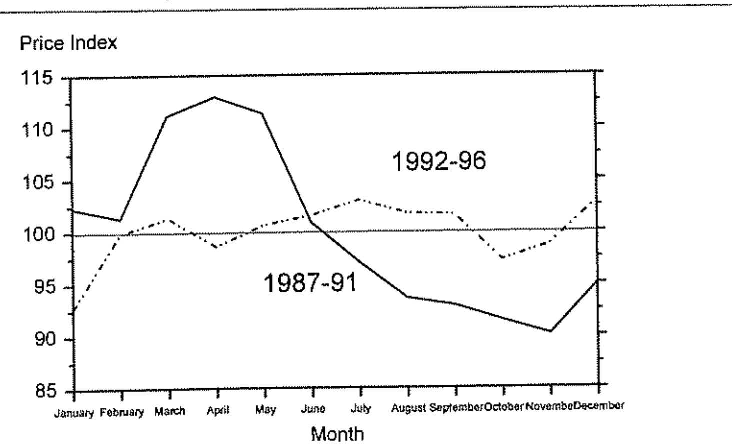
Seasonal lamb prices have characterized the sheep industry for decades, as noted by VanTassell and Whipple (1994). Seasonal price patterns result from a combination of supply and demand factors. Seasonal feeder lamb prices are likely driven more by seasonal lambing and production patterns, while seasonal retail prices are likely driven more by seasonal purchasing and consumption patterns. Ward (1995) shows seasonal price patterns for feeder lambs and slaughter lambs at San Angelo, TX, from 1984 to 1993. These patterns have persisted for several years. Both for feeder and slaughter lambs, prices were highest in the February-to-April period. Prices were seasonally lowest in the June-to-August months for feeder lambs and August-to-October months for slaughter lambs. Similar seasonal price patterns for feeder lamb, slaughter lamb and carcass lamb prices were found also for earlier periods (Stillman et al., 1990; Ward and Detten, 1984).

Figure 2 compares indexes of average monthly slaughter lamb prices for the past five years (1992 through 1996) with comparable figures for the preceding five years (1987 through 1991). Since phase-out of the National Wool Act began, the seasonal lamb price pattern appears to have changed. Prices were seasonally highest for March/April/May and lowest for September/October/November during the 1987 through 1991 period (Figure 2). Prices switched significantly for the 1992 through 1996 period. Prices were highest for July/December/ August and lowest for January/October/November. The change is likely a combination of supply and demand factors. Lower-than-usual supplies during some months may contribute to higher-than-normal prices. Potentially, increased imports of lamb during the spring months – when U.S. lamb prices typically peaked in anticipation of the Easter peak in lamb consumption – may have effectively placed a cap or ceiling on the traditional spring price increase. Perhaps more importantly, the question remains whether the change in seasonal prices is "permanent" or somewhat transitory while sheep producers adjust to the changes in price signals and agricultural policies.

Price Discovery

As noted above, price discovery is the process of buyers and sellers arriving at transaction prices. Packers begin with a simple profit function; profit equals total revenue minus total costs (Ward and Detten, 1984). Packers estimate their revenue from lamb carcasses or cuts, pelts and other by-products, subtract from estimated revenue their estimated slaughter-processing costs and a profit target, and the amount remaining is how much they can pay for slaughter lambs. Individual lambpacker buyers are given a "buy order" from the head buyer, usually daily. Individual buyers then visit lamb feeders, assess the sale lot of slaughter lambs being offered, and compute a bid price. Competition and lamb marketing conditions deter-

Figure 2. Seasonal price patterns for Choice slaughter lambs in San Angelo, TX (1987 through 1991 versus 1992 through 1996).



mine whether or not slaughter lambs are purchased within the buy order or whether adjustments must be made to the buy order.

Table 1 is an example of how buyers estimate a live weight bid price for slaughter lambs. Buyers begin with a wholesale carcass price or boxed lamb cutout value, estimate any discounts and premiums for lambs below or above the base standard, convert the adjusted carcass price or boxed lamb cutout value to a live weight price, add by-products value, subtract slaughter-processing costs and a profit target and arrive at a bid price. Then buyer and seller negotiate a sale price. The example in Table 1 assumes the following base or standard type of lambs: Choice grade, yield grades (YG) 1-3, 110 to 130 pounds, with No. 1 grade pelts. The pen of lambs is estimated to be 95% Choice grade, 85% YG 1-3, 60% 110 to 130 pounds, all with No. 1 grade pelts, estimated average weight is 125 pounds and estimated average dressing percentage is 51%. Assumed market prices are: Choice, YG 1-3, 55 to 65 pound boxed lamb cutout, $210.00 per cwt; YG 4-5 carcasses, $195/cwt; more than 65-pound carcasses, $205/cwt; Good grade or yearling carcasses, $185/cwt; and No. 1 grade pelt prices, $15 each. Table 1 indicates the steps in estimating a bid price.

Table 1 can be modified to illustrate a carcass or dressed weight bid example. *Step 2* in Table 1 is then omitted. In *Steps 3* and *4*, pelt value, estimated slaughtering-processing cost and the profit target (all expressed on a live weight basis in Table 1) are computed on a carcass weight basis (by dividing each by the dressing percentage). Then pelt value ($23.53) is added to the adjusted price ($204.50) and slaughter-processing costs ($28.24) and the target profit ($2.35) are deducted to arrive at the carcass weight bid price of $197.44.

Slaughter lamb prices for any given day or week fluctuate above or below the market level or average market price. One type of price discovery research attempts to determine factors that explain the variation in transaction prices. There has been relatively little of this type of research with slaughter lambs because access to transactions data are limited. Factors affecting transactions price variation for slaughter lambs are similar to those found for fed cattle. Factors affecting fed cattle prices (Jones et al., 1992; Ward, 1992; Schroeder et al., 1993; Ward et al., 1996) included: 1) boxed beef cutout values; 2) live cattle futures market prices; 3) cattle quality (including sex, weight, quality grade, yield grade); 4) sale lot size; 5) number of days between purchase and delivery of cattle; 6) number of packers bidding on cattle; 7) individual packing plants or firms; 8) individual feedlots; 9) day of the week; 10) time of year; 11) region of the country; and 12) extent and type of packer-controlled supplies.

Table 1. Slaughter lamb live weight price bid ($/cwt) example.

Step 1: Compute Adjusted Boxed Lamb Price	
Expected boxed lamb price (Choice, YG1-3, 55 to 65 pounds)	$210.00
Less discounts:	
% good × $ discount (5% × $25)	1.25
% YG4-5 × $ discount (15% × $15)	2.25
% heavy carcasses × $ discount (40% × $5)	2.00
Sum = Adjusted price	204.50
Step 2: Convert Adjusted Boxed Lamb Price to Live Weight	
Adjusted price × dressing percent ($204.50 × 51%)	104.30
Step 3: Add Pelt Value	
Pelt value ($15/liveweight cwts)	12.00
Adjusted liveweight price *(Step 2)* + pelt value ($104.30 + $12)	116.30
Step 4: Deduct Slaughtering-Processing Cost and Profit Target	
Slaughtering-processing cost ($18/liveweight cwts)	14.40
Profit target ($1.50/liveweight cwts)	1.20
Step 3 - Step 4 ($116.30 - $14.40 - $1.20) = Price Bid	$100.70

In one of the few similar studies for slaughter lambs, Ward (1984) studied the effect buyer competition had on slaughter lamb prices. He used transactions data from a newly organized teleauction for slaughter lambs in Oklahoma for the 1979-to-1982 period. Factors affecting the variation in slaughter lamb prices included wholesale carcass lamb prices and pelt prices, both as expected from derived demand theory, number of buyers bidding on lambs, specific buyers purchasing lambs and seasonality in prices.

Increased lambpacking concentration has been a concern of sheep producers and others. Menkhaus et al. (1990) used annual data from 1972 to 1985 in a model estimating the impact from the declining number of lamb slaughtering plants in the four largest lamb marketing states. Included in the model was a variable to measure the effects from packer feeding of slaughter lambs. Results suggested that even small numbers of packers may be competitive enough not to adversely affect slaughter lamb prices, so long as there is at least one significant firm competing for lambs. There was some evidence that increased numbers of buyers may lead to enhanced prices paid for slaughter lambs. Wholesale lamb prices, sheep and lamb slaughter and wage rates in meatpacking affected slaughter lamb prices as expected based on economic theory. Results for packer feeding were contrary to popular opinion. When the lamb feeding variable was significant, it was positive instead of negative. Packer feeding may enable packers to increase plant efficiency sufficiently enough for them to pay higher prices for slaughter lambs purchased in the cash market.

Brester and Musick (1995) studied the effects lambpacking concentration had on marketing margins over the period 1980 to 1992. Results from a three-stage least squares (3SLS) regression model indicated that increases in lambpacking concentration had small positive effects on marketing margins.

Marketing margins were far more sensitive to changes in marketing costs and by-product values than to packer concentration.

Ward and Hildebrand (1993) used sale summary and transactions data for 1991 to determine factors affecting slaughter lamb prices. Slaughter lamb prices were positively related to wholesale lamb prices as expected. Wholesale lamb prices are used as a starting point in the pricing process for slaughter lambs and wholesale prices represent an important component in the profit equation for packers. Six wholesale lamb price series were studied (i.e., prices reported for the Northeast and River markets) and for lamb carcasses weighing less than 55 pounds, 55 to 65 pounds and 65 to 75 pounds. There was relatively little statistical difference among the six wholesale lamb price series. Between weight groups, there was slightly better explanatory results for 55- to 65-pound carcasses, followed by carcasses weighing less than 55 pounds. Slaughter lamb prices also were positively associated with pelt prices. Pelt sales represent the largest component of by-products income for lamb-packing firms.

Marketing methods affected prices received for slaughter lambs. Prices received at auction markets were considered the base for comparison purposes. Prices were over $3/cwt higher for slaughter lambs marketed through electronic markets (i.e., teleauction and computer auctions combined). Direct marketing is the most common method of marketing slaughter lambs to lambpackers (Grain Inspection, Packers and Stockyards Administration [GIPSA], 1996). Direct marketing resulted in significantly higher prices in one model but not the other.

Often buyers pay a price premium for larger sale lots of livestock but the price premium is expected to decline as sale lot size increases. Results confirmed prior expectations but the price premium for larger sale lots was small. Prices were reported for slaughter lambs referred to in a variety of ways (i.e., spring, old crop, slaughter, feedlot and pasture lambs). Varying terminology was found to be confusing in another study of the sheep industry (Stricklin, 1987). Prices for spring lambs were considered the base for comparison purposes in the Ward and Hildebrand (1993) study. Significantly higher prices were found for spring lambs compared with other types of slaughter lambs.

A strong seasonal price pattern for slaughter lambs was found in this study (Ward and Hildebrand, 1993). Prices also varied among states where lambs were sold but the analysis did not include enough information to explain locational price differences.

Studies such as those reviewed here confirm that several factors influence slaughter lamb prices. In nearly all instances to date, econometric models confirm that slaughter lamb prices behave according to economic theory. However, price comparisons without the appropriate statistical analysis can be misleading and care must be exercised when interpreting observed prices because of the many factors which affect slaughter lamb prices.

Price Discovery Interactions with Price Determination

As noted at the beginning of this article, price determination and price discovery are interrelated. Price determination finds the market price level; and the general level of slaughter lamb prices may be high or low. However, when market prices are low or falling, questions and concerns about price discovery increase. Figure 3 is a matrix showing potential price discovery problems or concerns under given supply and demand scenarios. When demand is strong or expanding and when supplies relative to processing capacity are small or declining, price discovery problems are generally not a major concern. Under these conditions, competition is generally keen, thus enhancing efficient effective price discovery. The opposite extreme, weak or declining demand combined with large or expanding supplies relative to slaughter capacity, elicits considerable price discovery concerns.

Where has the sheep industry been the past few years? Where will it be in the next few years? Lamb production has been declining (Figure 1). Demand for lamb is more difficult to measure but Purcell (1995) argues that lamb demand has also declined. However, slaughter lamb prices have increased, as Figure 1 clearly shows. This has partly negated price discovery concerns. Some concerns still exist, especially related to packer concentration, fewness of slaughter facilities and packer-controlled supplies (i.e., packer feeding and forward contracting).

Slaughter Lamb Prices and Pricing: Future Needs

Several pricing issues face the sheep industry. Some are related to price

Figure 3. Price discovery concerns under alternative price determination conditions.

		Demand for Lamb	
		Strong or expanding	Weak or declining
Relative Supply of Lamb	Large or expanding	Potential concerns	Probable concerns
	Small or declining	Unlikely concerns	Potential concerns

determination. One example is the high cost of producing lamb. High production and processing costs in a markup pricing framework add to high retail lamb prices and inhibit consumer purchases of lamb (TAMRC Lamb Study Team, 1991). A component of lamb demand, consumer tastes and preferences, also plague lamb and hamper demand. Consumers perceived that lamb products suffered from quality and consistency problems, lack of convenience, and overall poor economic value (Ward et al., 1995).

Many other pricing issues are related to price discovery. Schroeder et al. (1997) conducted a study focusing on price discovery in the beef industry in the next ten years by interviewing all the major beefpacking firms and several large cattle feeding firms. They reported six major price discovery issues in beef. Some of the same six issues also pertain to lamb.

First, more accurate and less subjective measurements of lamb quality are needed. While the details of this are outside the purview of this article, a movement to a less subjective, more efficient grading system would be beneficial. This problem involves accurately and consistently identifying and sorting higher versus lower quality lamb carcasses. Then lamb can be targeted more efficiently to the appropriate consumer markets. Such a system has been proposed for beef and needs to be considered for lamb (Koohmaraie et al., 1996).

Closely related is the problem that price premiums and discounts for slaughter lambs do not adequately reflect value differences. Purcell (1995) noted that price signals are slow and inefficient. Research has shown that carcass weight and grade pricing better reflects wholesale value in beef (Feuz, Fausti and Wagner, 1993) and the same could be expected for lamb. Carcass pricing in 1994 was used significantly more by packers located in some regions than others, but less than half (46.6%) of all slaughter lambs were purchased on a carcass weight basis (GIPSA, 1996). Further movement toward value based pricing is needed for slaughter lambs.

Inadequate market information inhibits efficient price discovery. Purcell (1997) noted a sharp decline in public resources devoted to collecting and reporting market information. Yet, market information is essential for effective, efficient price discovery. Purcell argues that resources are needed to preserve and enhance market information because of its public good nature. In addition, if price-based open exchange systems fail to adequately coordinate supplies with demand, our market pricing system will be replaced by contracts and vertical integration. Anderson et al. (1997) found through experimental simulation for fed cattle that prices became more variable in the absence of market information, use of contracts increased and more cattle were marketed at less efficient weights.

Formula pricing arrangements adversely affect cash fed cattle markets. Contracting and formula pricing have their advantages as noted by Schroeder et al. (1997) for beef and similar advantages could be expected for slaughter lambs. However, questions arise regarding the interaction of increased concentration and use of packer-controlled forward purchases, (i.e., packer feeding and contracting). The number of lambpacking plants handling more than 300,000 lambs annually declined from 7 in 1980 to 5 in 1994 in the U.S. (GIPSA, 1996). The combined market share of the four largest lambpacking firms increased over the same period from 55.9% of total sheep and lamb slaughter to 75.5%. Packer feeding, which excludes forward contracting, increased from 10.1% of total slaughter in 1980 to 22.5% in 1994. Research is needed to assess the trade-off in packing plant efficiency from fewer and larger plants and increased use of packer-controlled supplies versus potential use of market power by packers. Results for the beef industry suggest cost efficiency gains exceeded any market power abuse (Azzam and Schroeter, 1995). The same may be found for the lamb industry, but no comparable work is available.

Group marketing of slaughter lambs may offer solutions to some price discovery problems. Sheep producers have at times advocated more group marketing efforts as a means of reducing some of the problems associated with slaughter lamb price discovery. The potential costs and benefits of such bargaining and vertical integration ideas should be studied.

A final pricing issue relates to lamb import impacts on slaughter lamb, wholesale lamb, and retail lamb prices. As domestic lamb production has declined, lamb imports have increased, both in absolute terms and as a percentage of domestic production (and consumption). Imported lamb may be imported to maintain a steady flow of lamb products to U.S. consumers. However, domestic price impacts from imported lamb are often assumed by sheep producers to be negative. Research is needed to address this issue.

Conclusions

In summary, several pricing issues face the sheep industry. Some can be addressed more quickly than others but most need attention for the sheep industry to thrive in the future. Two major questions follow. First, who will provide leadership for this necessary work if public support for sheep research and extension activities decline? Second, where will the resources come from for this research?

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Production Responses to Economic and Other Signals

Rodney Jones[1,2] and Ted C. Schroeder[3]

Summary

Sheep breeding inventories are not very responsive to economic signals. Although profits are clearly influenced by variations in costs and revenues, short-run changes in these factors have little impact on the size of the U.S. sheep and lamb industry. Even over longer time horizons economic factors that have large impacts on profitability only partially explain changes in industry size. On the revenue side, changes in the income received from lambs elicit larger inventory responses than changes in income received from wool. Of the cost factors examined, changes in grazable forage costs impact ewe inventories over time more than changes in other input costs. Since economic factors explain a portion of sheep inventory responses over longer time periods, the industry needs to continue to focus on efficiency in both production and marketing. Improvements are needed in sheep and lamb production technology, in forage production systems and predator control technology and in pricing system efficiency.

Key words: supply response, economic signals, economic efficiency.

Introduction

Over the past several decades the U.S. sheep and lamb industry has declined dramatically. Ewe inventory declined by 77% (an average of 4% per year) from 1961 to 1996; and during 29 of the last 35 years the ewe flock declined in size. The sheep industry produces two primary products, meat and wool, with each output targeted to a markedly different market. Through genetic selection industry participants have some ability to change the relative production of meat or wool in response to market signals.

Despite significant efforts by researchers and industry participants to identify causes of the prolonged sheep industry liquidation, few definitive answers prevail. There is little consensus regarding the factors causing the industry decline or what could be done to slow or reverse the trend. The industry decline has significant implications for lamb and wool producers as well as the industries supporting these commodities. Further research is needed to better understand this industry and develop strategies for long-term viability.

The purpose of this article is to document what is known about U.S. sheep supply response based upon previous literature and to present an updated model of sheep industry supply response. Previous authors have identified economic, policy-induced and other factors contributing to the decline in the U.S. sheep industry. This article summarizes previous findings and draws inferences from previous research. In addition, a dynamic supply response model of the annual ewe flock is estimated to discern factors contributing to the industry's decline. This model builds upon previous modeling efforts by incorporating more recent data and by considering factors not previously incorporated into sheep supply response models.

Literature Review

Two previous studies explicitly modeled factors affecting supply response in the U.S. sheep industry, and several additional studies provide insight into important contributors to supply response. Whipple and Menkhaus (1989) developed a dynamic model of U.S. sheep supply from standard profit maximization theory. The derivation resulted in a multi-equation model of the U.S. sheep industry. Ewe replacements retained were modeled as a function of lamb price, wool price and beef price (all normalized by alfalfa hay price) with appropriate lags deter-

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mined in the modeling effort. Labor price and a measure of lamb price risk were also included in the replacement equation. The ewe retention decision for ewes aged 2 through 8 years was modeled as a function of lamb price, wool price, and slaughter ewe price (all normalized by labor price) all lagged by one year. Additional explanatory variables included the number of non-slaughter sheep deaths, hay price, beef price and a measure of the productivity of ewes by age category. The total breeding stock sheep flock was estimated by adding the replacement estimates to estimates of the sum of breeding ewes ages 2 through 8 years retained in the U.S. ewe flock. Per animal live lamb weights were modeled as a function of lamb price, corn price and a time trend. Similarly, per animal fleece weights were modeled as a function of lagged fleece weight, price of wool and lamb prices. Multiplying these weight estimates by the total flock estimates resulted in annual lamb and wool production.

Whipple and Menkhaus (1989) used annual data from 1924 to 1983 to estimate supply responses by simulating changes in factors of interest over various time horizons. Elasticities of supply responses for lamb production, wool production and total breeding flock were calculated at alternative time horizons. As expected, supply responses became more elastic with increases in the time horizon. For example, lamb production own-price elasticity ranged from 0.01 at a 1-year time horizon to 11.38 at a 30-year time horizon. Similarly, wool production own-price elasticity ranged from 0 at year 1 to 11.53 at year 30.

Breeding flock retention elasticities were calculated with respect to lamb price, wool price, cull sheep price, hay price and labor price. All of these factors had calculated elasticities of 0 at a 1-year time horizon, suggesting supply response in the sheep and lamb industry occurs slowly. At longer time horizons (15- to 30-year) breeding sheep retention positively responded to lamb and wool prices and negatively responded to hay price, labor price and cull sheep price. The response to lamb price was larger than the response to wool price and the response to hay price was larger than the response to labor price.

Depending on the region, many activities can compete with sheep production for the base grazing resource. Examples include recreation use and alternative agricultural enterprises. For agricultural producers, beef production is the most common substitute for sheep production. Burton and Wollo (1986) concluded that net income from a combination beef and sheep farm could be increased by substituting more beef production for sheep when beef prices were high. A linear programming model indicated that variability in net income was reduced when beef and sheep numbers were allowed to vary. Therefore, beef prices are expected to be negatively related to ewe flock size. However, Whipple and Menkhaus (1989) found beef price to be positively related to breeding flock retention. They hypothesized that the unexpected statistical relationship may have resulted from the high positive correlation between beef and lamb prices during the sample period.

Purcell et al. (1991) surveyed sheep producers to obtain factors perceived to influence decisions regarding sheep flock expansion or contraction. Factors difficult to quantify such as producer preference for sheep production ranked high in the survey responses. Other important factors included relative profitability of the sheep enterprise, availability of range or pasture resources and facility capacity. In contrast to Whipple and Menkhaus (1989), this survey revealed that labor availability was not a primary factor in sheep enterprise expansion decisions. A second survey, however, indicated that when producers were directed to consider their own labor in the survey response, the labor issue became more important. Predator losses and concerns about decreases in productivity were also important deterrents to expansion of individual sheep operations.

Purcell et al. (1991) used the survey results, along with economic theory and previous literature, to develop a model of supply response in the U.S. sheep industry. In a single-equation supply model, they specified the "January 1 breeding ewe inventory" as a function of total returns per ewe, calf price, principle crop acreage, hay price and percent of part-time farms. "Total returns per ewe" were calculated using lamb prices, lambing percentages, wool prices, average fleece weights and wool incentive payments. The "calf price" variable and the "crop acreage" variable represented returns to competitive enterprises. "Hay price" represented the input costs in sheep production. The "percent of part-time farms" variable was included to capture subjective factors related to sheep production revealed by the surveys.

The models were estimated using annual data from 1953 to 1984. Models were estimated for the entire U.S. – and for each of 7 sub-regions within the U.S. – to account for regional differences in operation types and production practices. While results differed by region, the independent variables in general had the expected affects on sheep inventories. The exception was the crop acreage variable which exhibited an unexpected positive influence on sheep numbers in several of the regional models, as well as in the national model. Total returns had the expected positive influence on breeding flock inventories. Unlike Whipple and Menkhaus (1989), results suggested increases in cattle prices have the theoretically expected negative impact on sheep numbers. Increases in hay prices consistently negatively influenced sheep numbers as expected.

The national model was re-estimated using data through 1988 and sheep supply response elasticities were calculated at various time horizons. Similar to previous work, short-run supply elasticities were small. The long-run elasticity with respect to sheep returns (1.754) was significantly smaller than the estimate of Whipple and Menkhaus (1989; 11.4 for sheep price, 11.5 for wool price). The computed long-run elasticity with respect to calf price was quite small (-0.939) but did have the expected negative sign. In the long-run, increases in hay prices significantly influenced the breeding sheep flock with an elasticity of -1.839. The long-run elasticity of sheep inventories with respect to the proportion of part time farms was -2.788, supporting the hypothesis that changes in resource constraints have an impact on long-run breeding sheep inventories. The authors concluded that the fixed nature of many of the inputs used in sheep production may contribute to an asymmetric supply response. The implication is that inventory numbers decline more easily and more rapidly than they expand. Contrary to expectations, the crop acreage harvested had a large positive influence on breeding sheep inventories with a long-run elasticity of 3.256, suggesting that this variable may have been reflecting feed availability rather than the intended competing enterprise.

VanTassell and Whipple (1994) examined the cyclical nature of lamb prices and stock sheep inventory levels. Production cycles resulting from biological lags and economic forces may be important in efforts to examine production alternatives and supply responses. A better understanding of the cyclical patterns of inventories and prices may also assist producers and other lamb industry participants to make better management decisions.

The authors employed harmonic regression models to project potential cyclical price and inventory paths. The technique accounts for seasonal variation, cyclical patterns and long-term trends. Data for annual breeding stock inventories and monthly lamb prices from 1924 through 1993 were employed. Alternative time periods were considered to account for possible structural changes identified using Akaike's information criterion.

Using the entire data set, price cycles of 10 and 28 years and inventory cycles of 12 and 26 years were identified. Statistical structural change tests revealed that the nature of these cycles may have changed over time. Periods of structural change were identified in the late 1940s to early 1950s, and again in the late 1960s to early 1970s. The study did not attempt to identify specific reasons for structural change. However, the authors hypothesized that the earlier period of structural change may have been a result of events triggered by World War II. Reasons suggested for the second period of structural change included inflation, labor shortages, growth in the synthetic fiber industry, increases in federal grazing fees and banning of the use of certain toxicants for predator control. Changes in production technology, wool manufacturing developments and the advent of marketing cooperatives are additional factors that may have altered cyclical patterns.

In general, the authors concluded that the sheep industry exhibits cyclical behavior similar to the beef industry. Both prices and inventories cycle on 8- to 13-year intervals. Long-run cycles of 24 to 28 years are also present. VanTassell and Whipple (1994) observed a decline in cycle length over time. Technological advances may have shortened the biological response time and increased education and understanding of pricing factors along with improved market reporting may have increased the accuracy of producer perceptions over time. Finally, increasing costs and more variable prices may have forced producers to become more responsive to economic signals over time.

VanTassell and Whipple (1994) also observed a decrease in the amplitude of the inventory cycle over time, suggesting that the decrease in total sheep numbers over the period of study may have resulted in less inventory volatility. Conversely, an increase in the amplitude of the sheep price cycle over time was observed. This could be due to changes in consumer demand, increased variability in processor and retailer margins or other economic factors.

The efficiency of the lamb pricing system and the timeliness of price responses to rapid supply changes and other factors impact producers' abilities to respond to economic incentives. Jones and Purcell (1993) examined the speed-of-price transmission between levels of the lamb marketing system and the responsiveness of price to various factors. The authors used a vector autoregressive model (VAR) to investigate lamb pricing patterns. The lamb pricing system followed a price markup pattern with short-run price changes initiating at the farm level from supply factors. These changes took a long time to work through the pricing system to the retail level and incomplete price transmission was present in the system even at long-time horizons. These shortcomings in the pricing system could contribute to producer reluctance to react to short-run price incentives.

Ward (1984) analyzed the importance of buyer competition on the lamb pricing system. The number of buyers positively influenced both absolute and relative lamb prices and buyer market shares impacted selling prices. Changing number, size and location of lamb buyers in the U.S. were important to the price discovery process and to industry participant's ability to respond to economic incentives.

Parker and Pope (1983) discussed a myriad of factors believed to impact the sheep and lamb industry. In addition to economic factors, they identified policy factors that may contribute to production responses. In particular, changes in the animal damage control program by the Interior Department in the early 1970s – along with actions by the Environmental Protection Agency (EPA) about the same time – may have been particularly damaging to the sheep industry. These actions essentially prohibited the use of toxic chemicals for predator control. Alternative means of predator control have either not been as effective or have been cost prohibitive and inability to control predators was cited as a serious problem for Western range sheep grazers. The need to improve production efficiency in the sheep industry was discussed at length. The authors pointed out that a reduction in research and extension efforts committed to the sheep industry may be partly responsible for the slow rate of productivity improvement relative to other livestock industries.

Supply Response Model

Lamb and wool producers are expected to respond to economic incentives associated with lamb production relative to other opportunities. As such, ewe inventory would be expected to increase (decrease) as profitability of lamb and wool production increases (decreases) relative to other production opportunities. Two important issues must be considered in modeling sheep supply responses. First, because of biological production lags and breeding stock investment costs, aggregate ewe inventories do not change instantaneously in response to changes in economic conditions (i.e., lags in production response are inherent in lamb production in part because of the time it takes to breed, grow, retain and re-breed replacements). In addition, once a productive ewe is placed in the breeding flock, she is not likely to be culled quickly. Producers plan on a multi-year stream of lamb and wool sales to recapture the initial investment in a breeding ewe. Therefore, short-run changes in production will be much smaller than longer-run adjustments in response to changes in lamb profitability. Any lamb supply model needs to account for this dynamic supply response which may take several years to fully reflect changes in economic conditions.

Second, the biological lag in production also suggests that lamb producers make production decisions based upon expected profitability of lamb and wool production relative to other enterprises. There is little lamb producers can do to change production in the short-term when lamb profits are high versus when producers are losing money. However, they can change future production decisions when expectations suggest changes in future profitability. Lamb supply response modeling needs to include lamb producer expectations in the modeling framework.

The lamb and wool supply response model estimated here incorporates information from Purcell et al. (1991); VanTassell and Whipple (1994); Whipple and Menkhaus (1989); and Antonovitz and Green (1990) to develop a model of supply response in ewe inventories. The ewe inventory supply response model is:

Equation 1:

$$EWE_t = \beta_0 + \beta_1 EWE_{t-1} + \beta_2 REV_{t-2} + \beta_3 GRZ_{t-2} + \beta_4 FEED_{t-1} + \beta_5 CALFP_{t-3} + \beta_6 SIN(2\pi t/12) + \epsilon_t$$

Where:

t = year;
EWE = January 1 ewe inventory;
REV = gross revenue associated with lamb and wool production;
GRZ = private grazing fees;
$FEED$ = cost of feeding lambs;
$CALFP$ = calf price;
SIN = the sine function; and
ϵ = error term.

All variables are defined in Table 1.

Table 1. Summary statistics of annual data used to estimate ewe inventory supply response (1961 through 1995).[a]

Variable	Definition	Mean	Standard deviation
EWE (1,000 head)	January 1 ewe inventory; USDA, *Sheep and Goats.*	11,134	4,765
REV ($/ewe)	Revenue from lamb and wool production, 1995 dollars; calculated (see text).	86.48	15.39
LAMBP ($/cwt)	Lamb price, 1995 dollars; USDA, *Agricultural Prices.*	62.07	10.05
WOOLP ($/pound)	Wool price including incentive payment, 1995 dollars; USDA, *Agricultural Prices.*	0.94	0.25
GRZ ($/cow/month)	Cow grazing fees per head per month, 1995 dollars; USDA, *Agricultural Prices and Farm Real Estate Market Developments.*	9.28	0.94
FEED ($/ewe)	Other feed cost of producing finished lambs, 1995 dollars; calculated (see text).	49.29	5.07
HAYP ($/ton)	All hay marketing year average U.S. price, 1995 dollars; USDA, *Agricultural Prices.*	70.31	9.21
MILOP ($/cwt)	Grain Sorghum marketing year average U.S. price, 1995 dollars; USDA, *Agricultural Prices.*	4.54	0.74
SBMP ($/ton)	Soybean meal marketing year average U.S. price, 48% protein, 1995 dollars; USDA, *Agricultural Prices and Oil Crops Yearbook.*	221.25	60.26
CALFP ($/cwt)	Calf annual average U.S. price, 1995 dollars; USDA, *Agricultural Prices.*	73.12	15.62

[a] All prices, revenues and costs were deflated to 1995 constant dollars using the Producer Price Index obtained from USDA, Agricultural Prices.

The lagged-dependent variable is included to make the model dynamic and account for rigidities in ewe retention and culling decisions described above. The estimate of β_1, referred to as "one minus the partial adjustment coefficient," is expected to be between 0.0 and 1.0 (Nerlove, 1972). A value close to 0.0 suggests rapid response of sheep producers to changes in economic conditions, and a value close to 1.0 indicates slow response (i.e., large differences between short- and long-run supply responses).

Lags associated with *REV*, *GRZ*, *FEED* and *CALFP* are included because producers base supply decisions upon *expected* values of these economic factors. Producer expectations have been modeled in many ways including various forms of naive expectations (reviewed by Askari and Cummings, 1977); futures prices (Gardner, 1976); adaptive expectations (e.g., Antonovitz and Green, 1990); and rational expectations (Irwin and Thraen, 1994). Antonovitz and Green (1990) tested several different cattle producer price expectation models and determined that no single model outperformed all others. In addition, because no lamb futures market exists, and the nature of multiyear ewe retention, decisions would not likely be made based upon short-term futures prices. Naive expectations were used here, assuming expectations are based on past values. The lag lengths for the variables were based on prior work by Purcell et al. (1991) and upon model fit.

Expected revenue from lamb and wool production (*REV*) is defined as:

Equation 2:

$$REV_t = (LAMBP_t \times 1.2 \times LCPER_t) + (8.5 \times WOOLP_t)$$

Where:

LAMBP = lamb price (\$/cwt) and is multiplied by 1.2 cwt/lamb to convert to \$/lamb;
LCPER = lamb crop as a percent of ewe inventory (%); and
WOOLP = wool price (\$/pound) plus the government wool price incentive payment (\$/pound) times 8.5 pounds of wool/ewe.

Values for wool production and average lamb weight were obtained from Warmann (1996). Expected revenue is expected to be positively associated with ewe inventory.

Grazing fees (*GRZ*) are included in the model to account for costs associated with grazing the breeding flock. They are expected to be negatively associated with ewe inventory as are other feed costs. Feed costs (*FEED*) are costs associated with feeding ewes and lambs that are not included in the grazing costs. Feeding costs were calculated as:

Equation 3:

$$FEED_t = 457 \times HAYP_t + 629 \times MILOP_t + 42 \times SBMP_t$$

Where:

HAYP = hay price(\$/pound);
MILOP = grain sorghum price (\$/pound); and
SBMP = soybean meal price (\$/pound).

Coefficient weights represent the pounds per ewe required to produce finished lambs assuming a 140% lambing rate as estimated by Spaeth (Warmann, 1996). Silage and pasture costs are not included in this feed cost variable. Silage prices are expected to be highly correlated with hay and milo prices and pasture rental is included in the grazing fees variable.

As discovered by Burton and Wollo (1986), calf production is potentially a profitable substitute for lamb and wool production. As such, *CALFP* (calf price) is included to account for this substitutability. The sign of this coefficient is expected to be negative.

The *SIN* function is included to account for ewe inventory cyclicality. VanTassell and Whipple (1994) found 10- to 13-year short-run and 25- to 27-year long-run ewe inventory cycles. The best fitting sine function here was for a 12-year short-run inventory cycle, as specified in Equation 1.

Data

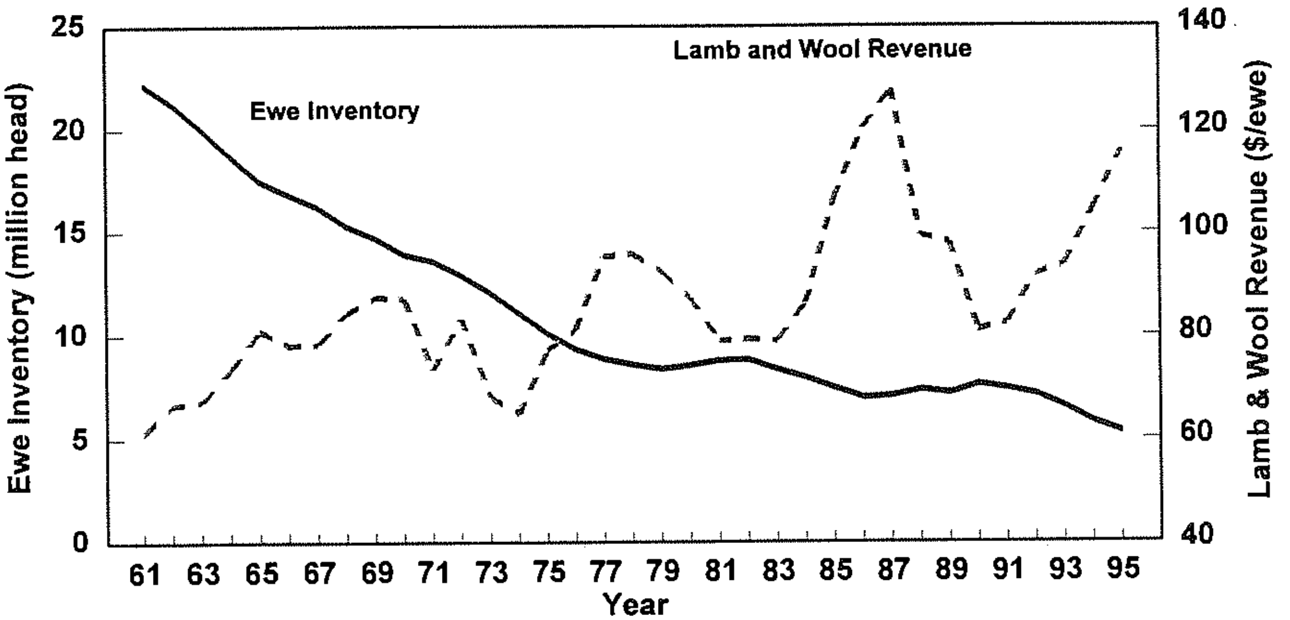
Annual data covering the 35-year period from 1961 to 1995 were used for model estimation. Price data were taken from Agricultural Prices (USDA, various issues), prices for milo, soybean meal and all hay were marketing season averages. Ewe inventory and lamb crop percentages were obtained from Sheep and Goats (USDA, various issues). Grazing fees from 1979-95 were obtained from Agricultural Prices and prior to 1979 were collected from Farm Real Estate Market Developments (USDA, various issues). Data availability necessitated using grazing fees in \$/head/month for grazing cattle which would be expected to follow the same general pattern as sheep grazing fees. All monetary data were adjusted for inflation by deflating to real 1995 dollars using the Producer Price Index from *Agricultural Prices* (USDA, various issues).

Summary statistics of the data are presented in Table 1. Although the average January 1 ewe inventory was about 11 million head, a steady downward trend in ewe numbers occurred over the 35-year time period. Figure 1 illustrates ewe inventory which declined from over 22 million head in 1961 to 5.3 million in 1995. Also included in Figure 1 is the calculated real lamb and wool revenue (*REV*). Despite increases in real lamb and wool revenue per ewe, ewe numbers continued to decline. Both lamb prices and overall real calf prices have been highly variable over the 1961-95 period. However, both have tended to increase by a small amount over time (Figure 2). Feeding costs have also varied over time, but have little discernable trend (Figure 3). Conversely, real grazing fees have trended upward during the past 35 years.

Results and Discussion

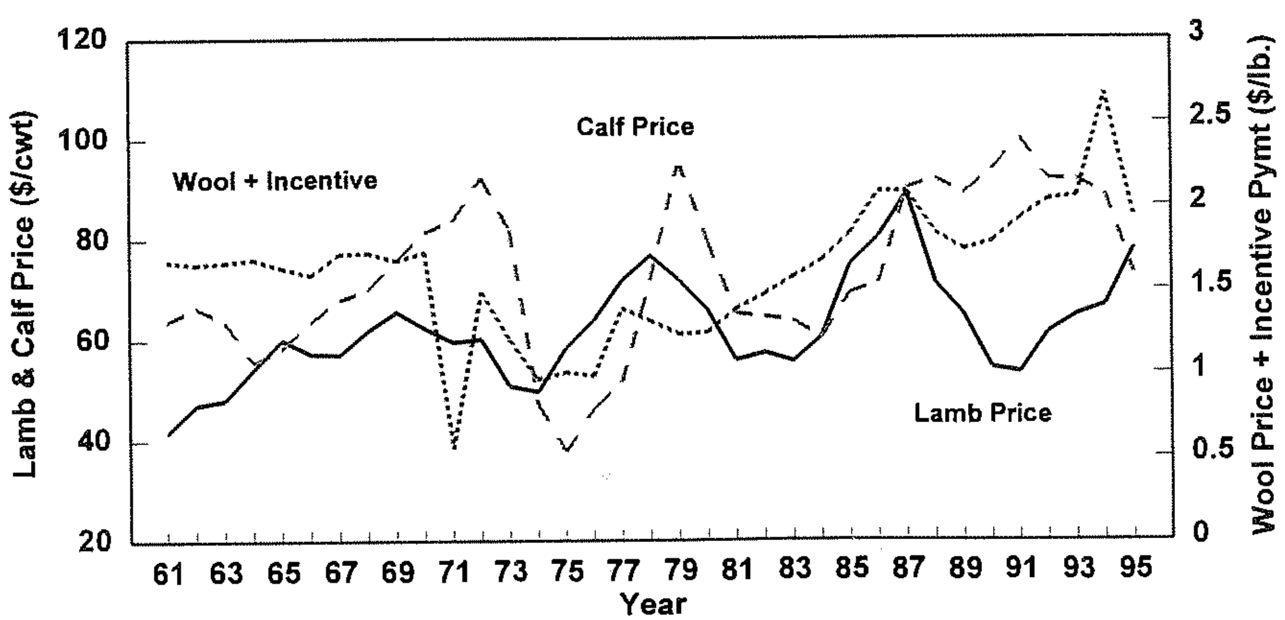
Equation 1 was estimated using iterative generalized least squares regression correcting for first-order autocorrelation with standard errors calculated using the technique outlined in Dhrymes (1971) to account for the lagged-dependent variable. The model was estimated using the *SHAZAM* software package. Parameter estimates of the model are presented in Table 2. The R-square is 0.997, suggesting a high degree of explanatory power as is often the case with a lagged-dependent variable included in the model.

Figure 1. January 1 ewe inventory and annual real lamb and wool sales revenue (1961 through 1995).[a]



[a] Source: *Agricultural Prices* (USDA, various years).

Figure 2. Real lamb, calf and wool (incuding incentive payment) prices (1961 through 1995).[a]



[a] Source: *Agricultural Prices* (USDA, various years).

All parameter estimates are of the expected sign and all are statistically different from zero at the 0.05 level. The model closely tracks actual historical ewe inventory numbers as revealed in Figure 4, which shows actual and predicted values.

Elasticity estimates are reported in Table 3. Elasticities indicate the percentage change in ewe inventory associated with a 1% change in each respective independent variable. Short-run elasticity estimates are the immediate response (with appropriate lag) of ewe inventory to a change in each variable. Five-year elasticity estimates indicate the magnitude of response in ewe numbers to a 1% change in each variable after a period of 5 years. The long-run elasticity measures ewe inventory response over ten or more years following a one-time shock to each variable independently.

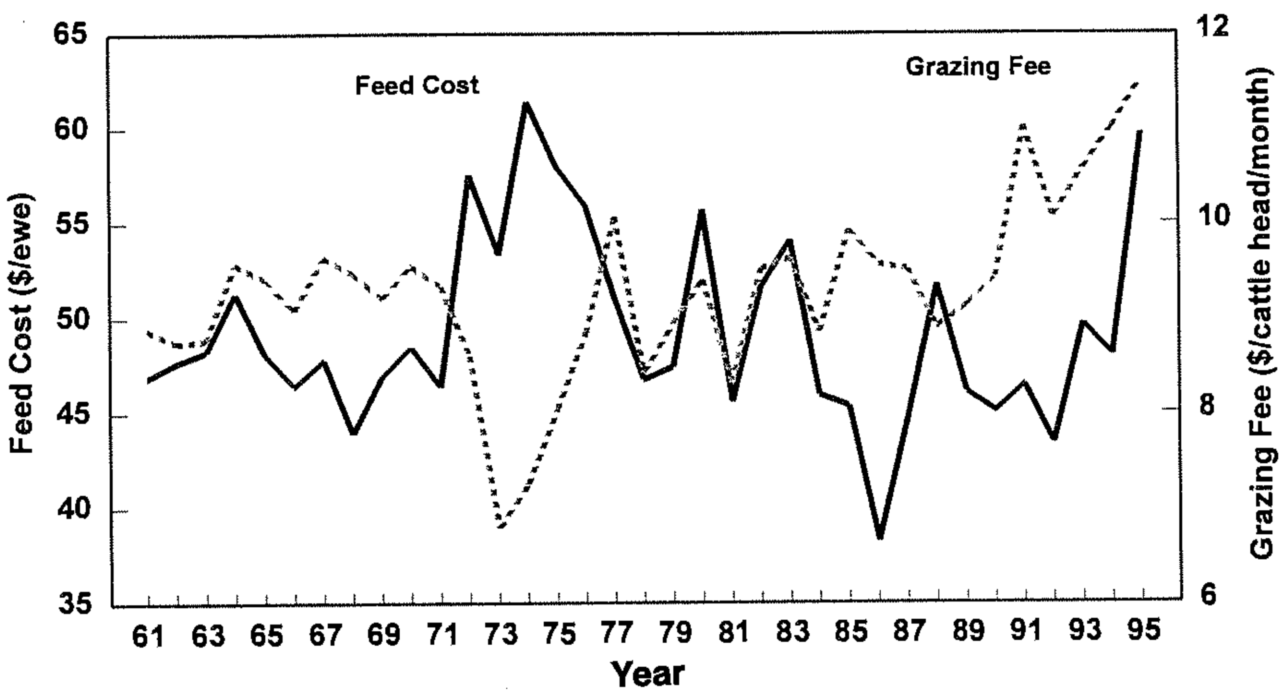
An important point to note is that all elasticities are quite small indicating that ewe inventory is not very responsive to changes in the respective variables. A 1% increase in revenue associated with lamb and wool production on average only increases ewe numbers by 0.146% in the short-run, by 0.666% after 5 years (intermediate-run) and by only 3.175% in the long-run. Lamb and wool prices have even smaller respective elasticity estimates. The long-run wool price elasticity of only 0.490% suggests that despite the fact that the federal wool incentive

Table 2. Parameter estimates of annual ewe inventory supply response (1961 through 1995).

Variable	Parameter estimate[a]	Significance level
Intercept	1828.2	0.079
EWE_{t-1}	0.954	0.000
REV_{t-2}	17.361	0.000
GRZ_{t-2}	-211.86	0.001
$FEED_{t-1}$	-20.235	0.050
$CALFP_{t-3}$	-5.045	0.019
$SIN(2t\pi/12)$	-183.71	0.000
ρ (first order auto-correlation parameter)	-0.244	0.150
R-square	0.997	–
Root mean squared error	208.11	–
Observations	32	–

[a] The parameter estimates represent the absolute change in the dependent variable (ewe inventories) associated with a 1-unit increase in the respective variable.

Figure 3. Real lamb feed cost and grazing fees (1961 through 1995).[a]



[a] Source: *Agricultural Prices* and *Farm Real Estate Market Developments* (USDA, various years).

payment has historically represented a significant portion of producer income, elimination of the payment is likely to have only a small impact on ewe numbers. In addition, recent high lamb prices are not likely to spur large increases in ewe numbers, especially over the next several years. Lamb and wool supply (i.e., lamb production) is simply not very responsive to changes in expected sale prices which suggests the industry will not see rapid expansion even with recent profits.

Increases in grazing rental rates have a large impact on ewe inventory. Over the long run, a 1% increase in grazing rental rates leads to a 4.147% reduction in ewe inventory. This demonstrates the need for cheap forage to encourage lamb and wool production. Increases in federal grazing fees lead to smaller lamb production. Other feed prices also have small elasticity estimates. Milo price has the largest feed ingredient elasticity with a long run estimate of -1.219. Soybean meal prices have little impact alone on ewe inventory with a long run elasticity of only -0.202.

Calf prices have an impact on ewe inventory, suggesting that lamb producers switch from lamb production to calf production in response to changes in calf prices. However, consistent with other variables, this elasticity is small. A 1% increase in calf prices leads to a 0.815% decline in ewe inventory in the long-run.

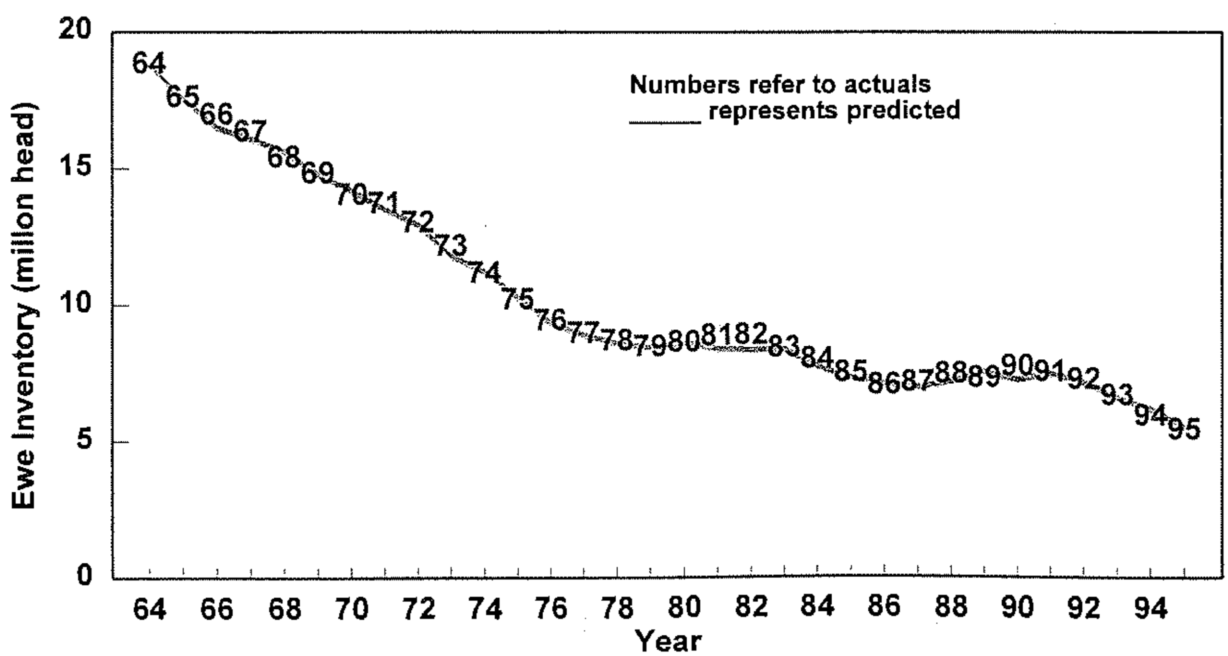
A comparison of our intermediate-run elasticity estimates with those of previous research is presented in Table 4. While variables included in the models differ somewhat, our estimates of revenue and calf price elasticities are consistent with Purcell et al. (1991). Previous researchers found a much larger response to hay prices, suggesting that the inclusion of other factors such as grazing fees and other feed prices in our model may have captured some the impacts previously attributed to hay prices. Results of this study suggest a significantly more inelastic intermediate-term response to lamb and wool prices than Whipple and Menkhaus (1989).

Table 3. Estimated elasticities of ewe inventory supply response.[a]

	Response time		
Variable	Short-run	5-year	Long-run
REV	0.146	0.666	3.175
LAMBP	0.127	0.578	2.758
WOOLP	0.023	0.103	0.490
GRZ	-0.191	-0.870	-4.147
FEED	-0.098	-0.445	-0.140
HAYP	-0.032	-0.146	-0.698
MILOP	-0.056	-0.256	-1.219
SBMP	-0.009	-0.042	-0.202
CALFP	-0.035	-0.171	-0.815

[a] The elasticity estimates represent the expected percentage change in ewe inventories associated with a 1% change in the respective variable.

Figure 4. Model-predicted and actual January 1 ewe inventory (1964 through 1995).



Conclusions

Sheep breeding inventories are not very responsive to important economic variables. For example, in the short-run, revenue increases have little effect on the size of the U.S. lamb industry. Similarly, increases in costs of production do not elicit significant short-term supply responses. The industry is somewhat more responsive in the intermediate- and long-term, however, economic factors still contribute only modestly to expansion or contraction of the U.S. sheep and lamb industry. Apparently a combination of economic forces along with other factors drive the industry. Non-economic factors include such difficult to quantify elements as producer attitudes toward sheep production as noted by Purcell et al. (1991).

In spite of the apparent importance of non-economic factors, long-term profits will need to be maintained before the industry will expand. Product selection and consistency at the retail level may need to be expanded and improved, however product price is a driving factor in determining market share. To achieve both long-term profitability and have a competitive retail product price, efficiency gains will have to be achieved. Parker and Pope (1983) point out that productivity has increased less in sheep production than in other livestock industries. It is important that the industry make both productivity and efficiency gains in order to compete with other livestock products in the marketplace. This will require research efforts directed toward not only sheep production systems, but also toward auxiliary fields such as more efficient forage production systems and more economical and effective predator control methods. The efficiency of the marketing system will also have to be improved. Failure to develop a more profitable domestic industry, and to encourage reluctant prospective lamb producers to enter the industry, will result in more lamb imports displacing domestic production.

Elimination of the wool subsidy program will likely have only a small impact on the size of the industry, even in the long-run. Of the revenue components in the lamb industry, lamb prices are of far greater significance in terms of eliciting supply responses. On the other hand, increased grazing fees on public land have greater consequences. Ewe inventories are very responsive to grazing fees, especially over long time periods. Historically the ability to utilize high forage diets has been advantageous for sheep production. However, as forages have become relatively more expensive compared to other feed sources, this advantage has declined.

Clearly, efforts to revitalize the U.S. sheep and lamb industry will need to have a long-term focus. Breeding herd inventories will not expand rapidly. Long-term efforts that improve productivity and economic efficiency in the industry could, however, result in industry growth.

Table 4. Comparison of 5-year ewe breeding stock elasticities across studies.

	Study, 5-year elasticity estimate		
Variable	Jones and Schroeder	Purcell, Reeves and Preston	Whipple and Menkhaus
REV	0.666	0.546	–
LAMBP	0.578	–	1.38
WOOLP	0.103	–	0.59
GRZ	-0.870	–	–
HAYP	-0.146	-0.572	-0.78
CALFP	-0.171	-0.290	–

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The Uniqueness of Lamb: Nutritional and Sensory Properties[1]

J.J. Jamora[2] and K.S. Rhee[2,3]

Summary

The nutritional value of lamb is comparable to that of other red meats. Animal diet, age and sex – as well as postmortem factors such as fat trim level and cooking – can cause changes in nutrient composition. Nevertheless, it is a good source of protein, minerals and B vitamins. Despite this, consumption of lamb remains low in the United States and many other countries, partly because many people do not like its characteristic species-related flavor.

The intensity of this flavor can be influenced by animal diet, age, sex, and breed, meat pH, and the extent and type of cooking. Various chemical compounds have been implicated to be responsible for the ovine flavor. Of those compounds, medium-length branched-chain fatty acids have been confirmed to be the most important. However, definitive generalizations regarding sheep production management practices which would yield meat with the most desirable flavor attributes cannot be made yet. Meanwhile, utilization of lamb as well as mutton may be increased by using processing methods which can reduce or modify the species flavor.

Key words: nutrient composition, flavor, palatability, sensory, chemical components.

Introduction

The meat from sheep *(Ovis aries)* is consumed all over the world in varying degrees. Consumption of sheep meat varies among countries for many different reasons. One of these is the culture or tradition of the particular country. Middle Eastern countries have a history of sheep meat consumption and have a specific demand for it (Young et al., 1994). There also are no religious restrictions to eating sheep meat. As late as 1993, New Zealand led in per capita annual consumption of lamb and mutton which, together with goat meat, averaged 56 pounds (Putnam and Allshouse, 1994). On the other side of the spectrum, each American consumed an average of only 1 pound of lamb, compared to 62 pounds of beef and 49 pounds of pork (Putnam and Allshouse, 1994). This low consumption arises despite the fact that sheep meat has comparable nutrient profiles to other red meats (beef, pork, veal) which generally are considered to be well-balanced nutritionally. The low use of lamb by U.S. consumers may be due partly to their dislike of or general unfamiliarity with its flavor, particularly the distinct species-related flavor. Research efforts have focused on documenting the chemical constituents responsible for lamb/mutton flavor and the environmental and genetic factors affecting this species flavor, as well as finding ways to reduce or modify it.

In this review, nutrient profiles compiled and summarized by the National Live Stock and Meat Board (NLSMB, 1988) from the USDA Agriculture Handbook 8 series, including the Handbook No. 8-17 (USDA, 1989) and the USDA Nutrient Database for Standard Reference – Release 11 (USDA, 1996), serve as main references for the nutritional properties of lamb.

The nutrient profiles of major red meats are essentially similar, so special mention is given to only those nutrients of which lamb and other red meats are known to be good sources and those that are involved in special health concerns. The sections on sensory properties of lamb, with a focus on flavor, summarize prominent studies that have been conducted. Since there have been more extensive reviews on the subject of lamb/mutton flavor alone (Sink and Caporaso, 1977; Cramer, 1983; Young et al., 1994), this review provides a more general idea

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regarding the past findings and present trends.

Nutritional Value of Lamb

Lamb versus Beef and Pork

Lamb was compared to beef and pork, because they are the most commonly eaten red meats. Due to variations in cooking methods and fat trim levels of meat cuts, comparisons between species were made mainly for the raw, separable lean portion of retail cut composites. Nevertheless, Table 1 compares nutrients provided by a 3-ounce serving of cooked lean meats as percentages of the Recommended Dietary Allowances (RDA; NRC/NAS, 1989). Cooking can increase the concentration of some nutrients (e.g., protein and fat) by loss of moisture and decrease heat-labile nutrients (e.g., some of the vitamins). Although some nutrient values may differ between species, a difference of less than 5% of the RDA may be considered of little practical nutritional significance (Ono et al., 1984).

The protein content of lamb is similar to that in beef and pork – about 20 to 21 g/100 g separable lean. Compared to proteins from plant sources, meat proteins are highly digestible. Like beef and pork, lamb provides all the essential amino acids in proportions that easily meet nutritional requirements (Schweigert, 1987).

The amount of fat in foods and the fatty acid makeup of the fat, along with dietary cholesterol level, have become a diet/health focus in today's health-conscious society, because these have been linked to several diseases, most notably cardiovascular diseases.

Total fat content of lamb (5.25 g/100 g separable lean) is about 17% and 22% lower than that of beef (6.33 g) and pork (6.75 g), respectively. In all three species, less than half of the fatty acids in the lean is saturated. Table 2 presents the fatty acid percentage compositions calculated by Rhee (1992) from the sample weight-based data of NLSMB (1988).

Saturated fatty acids (SFA) are the main dietary factor responsible for raising blood cholesterol level, whereas polyunsaturated fatty acids (PUFA) aid the body in lowering the level of newly formed cholesterol (AHA, 1997b). Lamb strikes a balance, as it is intermediate between beef and pork in SFA and PUFA percentages. Monounsaturated fatty acids (MUFA) may also aid in the reduction of blood cholesterol as long as dietary saturated fat is very low (AHA, 1997b). The percentage of MUFA is lowest for lamb among the three species. However, MUFA still constitutes the majority of the fatty acids in lamb, and % MUFA is higher for lamb than for veal or chicken (Table 2).

Cholesterol content is slightly higher for lamb (72 mg/100 g lean) than for pork and beef (65 and 60 mg, respectively; NLSMB, 1988). Cholesterol intake usually has less influence on blood cholesterol levels than SFA intake since some of the excess dietary cholesterol is removed from the body through the liver (AHA, 1997a).

Meat, in general, is an excellent source of certain minerals and several B vitamins (Schweigert, 1987). Amounts of various minerals are only slightly different among lamb, beef and pork (NLSMB, 1988). Meat provides iron with a high degree of bioavailability. Meat also increases the absorption of iron from other foods in the same meal (Schweigert, 1987). Among the three species, beef provides the most iron (2.3 g/100 g lean), followed by lamb (1.8 g) and pork provides the least (1.0 g) (NLSMB, 1988). Lamb is also a relatively good source of zinc and phosphorous.

Sheep meat or beef contains a relatively constant amount of B vitamins regardless of whether they are supplied in the animal feed or not, because microorganisms in the rumen of sheep and cattle are able to synthesize them (Schweigert, 1987). Like beef, lamb is a good source of vitamin B_{12} and provides more niacin than beef or pork (Table 1). However, lamb provides less than half the amount of vitamin B_6 compared to the other two species.

Domestic versus Imported Lamb

In 1996, U.S. lamb and mutton production totaled 269 million pounds, down 7% from 1995 (NASS, 1997). About 70 million pounds were imported (USDA, 1997). About half of the imported lamb comes from New Zealand (N.Z.) and the other half from Australia (USDA, 1997). Lin et al. (1988) documented nutrient profiles of typical N.Z. and

Table 1. Selected nutrients provided by a 3-ounce (84 g) serving of different cooked red meats as percentages of the U.S. Recommended Dietary Allowances.[a]

	Meat[b]		
Nutrients	**Beef, lean**	**Lamb, lean**	**Pork, lean**
Protein	41	38	36
Iron	27	17	1
Zinc	40	30	19
Thiamin	5	6	39
Niacin	19	28	22
Vitamin B_6	16	7	18
Vitamin B_{12}	57	56	18
Food energy[c]	10	9	10

[a] For males 25 to 50 years old. (Source: Calculated from data compiled by the National Live Stock and Meat Board [NLSMB, 1988] and Recommended Dietary Allowances [NRC/NAS, 1989]).

[b] Composite of retail cuts cooked by braising, roasting or broiling.

[c] Based on daily caloric intake of 2,000 kcal.

U.S. lambs. The USDA Agriculture Handbook No. 8-17 (USDA, 1989) includes these data. For the raw, separable lean portion of the retail cuts composite of Choice grade, protein content and amino acid composition were not significantly different between U.S. and N.Z. lambs (USDA, 1989). The lean from N.Z. lambs was lower in total fat content and slightly higher in moisture compared to the lean from U.S. lambs. Fatty acid composition differed considerably. Total MUFA and PUFA levels (as % of total fatty acids) were higher in the lean of U.S. lambs compared to that of N.Z. lambs (47% vs. 45% for MUFA, 11% versus 6% for PUFA). This may be a reflection of different feeding practices in the two countries (Lin et al., 1988). The type of animal diet can influence tissue fatty acid composition and is reviewed in a subsequent section. Cholesterol is only about 10% lower in U.S. lambs (65 vs. 74 mg/100 g lean than in N.Z. lambs).

Lin et al. (1989) compared U.S. and N.Z. lambs for the mineral composition of lean tissue from retail cuts. U.S. lambs had approximately 27% less calcium than N.Z. lambs, but had higher concentrations of other minerals although differences were not always significant. Most notable were iron, zinc and magnesium which were higher in U.S. lambs by approximately 20%, 30% and 37%, respectively. Differences in feeding regimen, age and geographical location were cited as possible causes of variations in mineral content. In an average serving size of about 3 to 4 ounces, all the differences between U.S. and N.Z. lambs may be of little practical nutritional significance (Lin et al., 1988, 1989). Greenfield et al. (1987) analyzed the nutrient composition of raw and cooked Australian lamb cuts as part of their national program of analyses to produce updated food composition tables. However, comparisons of their results with data on U.S. lambs are difficult due to differences in retail cuts.

Fat Trim Level Effects

So far, the nutrient profile of the separable lean portion of lamb retail cuts composite has been discussed. However, when analyzing lamb cuts as merchandised, with no separation of lean and fat portions, fat trim level must be specified.

Over the last three decades, total carcass fat for red meat-producing animals has been greatly reduced. The retail cuts of lamb analyzed for the USDA Agriculture Handbook No. 8-17 (USDA, 1989) had a maximum of 1/4- inch external fat layer. When Harris et al. (1990) conducted a national market basket survey of lamb in 6 cities across the U.S. in 1989, an overall average fat thickness of lamb retail cuts was about 1/7-inch. Recently, nutrient profiles of lamb cuts have been updated to take into consideration the reduction of external fat layer thickness to 1/8-inch. The new data can be found in the USDA Nutrient Database for Standard Reference – Release 11 (USDA, 1996). Total lipid (extractable fat) content of retail cuts has decreased by about 14% – from 21.6 (NLSMB, 1988) to 18.7 g/100 g – due to fat trim reductions. As a result, protein (and amino acids) as well as most of the vitamins and minerals increased.

Table 2. Fatty acid profiles (percent of total fatty acids) of raw separable lean and separable fat for different red meats (retail composite data).[a]

	Beef		Lamb		Pork	
Fatty acid	Lean	Fat	Lean	Fat	Lean	Fat
10:0	0.00	0.49	0.22	0.31	1.06	0.08
12:0	0.00	0.33	0.22	0.53	0.16	0.13
14:0	3.11	3.80	3.13	4.79	1.31	1.40
16:0	25.96	28.17	22.82	24.90	24.39	24.00
16:1	4.39	6.16	3.58	3.17	3.44	3.02
18:0	13.53	14.00	13.87	15.70	11.95	13.17
18:1	48.33	42.81	42.73	40.71	45.50	45.85
18:2	3.66	2.37	8.05	6.07	9.66	10.13
18:3	0.18	1.70	1.57	2.09	0.65	0.97
20:4	0.54	0.00	1.12	0.19	1.31	0.28
Other SFA[b]	2.19	–	1.79	–	0.33	–
Other MUFA[c]	2.19	0.17	0.89	–	1.15	0.86
Other PUFA[d]	0.37	–	0.00	–	0.00	–
Total SFA[b]	44.79	46.78	41.96	46.23	38.30	38.91
Total MUFA[c]	50.45	49.15	47.20	45.42	50.08	49.71
Total PUFA[d]	4.75	4.07	10.74	8.35	11.62	11.38

[a] Source: Rhee, 1992.

[b] SFA = saturated fatty aids.

[c] MUFA = monounsaturated fatty acids.

[d] PUFA = polyunsaturated fatty acids.

The reduction of external fat layer thickness is not the only change that can affect nutrient profiles of lamb and other meats. The removal of more seam (intermuscular) fat, developments in animal genetics, and other changes in production methods are likely to result in further changes of meat nutrient profiles (NLSMB, 1988).

Fatty Acid Composition and Cholesterol

Lamb versus Other Red Meats and Poultry

Although overall nutritional value of lamb is similar to that of beef or pork from a practical point of view, considerable differences in the total amount of fatty acids and the proportions of different fatty acids may be found among these red meats as well as between poultry and the red meats. Rhee (1992) provided the fatty acid profiles of the knife-separable lean and fat portions of retail cuts for various meats (beef, pork, lamb, veal, chicken breast) as percentages based on total fatty acid content. Those data are used in subsequent comparisons of lamb with other species. The fatty acid profiles for the lean and fat of lamb, beef and pork are shown in Table 2. For other species, the reader is referred to the data source (Rhee, 1992). The differences to be cited are variations in numeric values and may or may not be nutritionally or practically significant.

For SFA in the lean, lamb (U.S.) has the lowest percentage in palmitic acid (16:0) and the highest in myristic acid (14:0) among those species compared. Percentages of MUFA – mainly oleic (18:1) and palmitoleic (16:1) – are similar for lamb and other species. The PUFA – linoleic (18:2) and linolenic (18:3) acids – are not synthesized by the human body and are thus called "essential." The proportion (%) of 18:2 in the lamb lean is more than 50% (0.5-fold) higher than that in the beef lean, but lower than the levels in pork, veal and chicken. The percentage of 18:3 is highest for lamb lean; chicken breast, the meat with the second highest percentage, has a 30% (0.3-fold) lower percentage than lamb. It is not known why these PUFA are much higher in lamb lean compared to beef lean, which also is a ruminant meat. The differences may be partly related to the diet/feeding history of the animals used for analyses. The USDA Agriculture Handbook 8 series do not provide the dietary history (e.g., the type of diet or time-on-feed for grain finishing) of animals used which can influence the fatty acid composition of meat samples analyzed.

The fatty acid composition of adipose tissue differs from that of muscle tissue. In lamb (U.S.), the proportion of total SFA is about 10% (0.1-fold) higher in the separable fat than in the separable lean. The same trend is true for the other red meats, although it is not as pronounced in pork. Total MUFA and PUFA percentages are lower in lamb fat than in lean. Lamb fat is only second to pork in percent 18:2, with veal and beef following. As in the lean, the percentage of 18:3 in the separable fat is highest for lamb.

Separable fats from lamb and beef have virtually the same degree of saturation, based on the data on retail cuts composites, whereas lamb subcutaneous fat has been viewed to be more saturated than beef subcutaneous fat (Pearson et al., 1977). Presumably, the discrepancy could be related to variations in animal feeding regimen and the way *trans* and positional isomers of certain unsaturated fatty acids are analyzed and reported (Rhee, 1992). The subcutaneous fat of lamb has been described as "firm and flaky" (Vimini et al., 1984). Lamb fat is also often regarded as "waxy" in mouthfeel (Young et al., 1994), a term seldom used for beef fat. The primary predictor of the consistency of lamb or beef fat differs among reported studies (i.e., the concentration of 18:0 or 18:2, MUFA-to-SFA ratio, or the proportion of total unsaturated fatty acids) and the best predictor remains uncertain due to poor reliability of procedures used to measure consistency (Enser, 1995). Another possibility is that the consistency difference between lamb and beef fats may be partly related to potential differences in their polymorphism. Lamb fat may have a different polymorphic behavior from beef fat (i.e., lamb fat may crystallize in a different form than beef fat). It is well documented that beef tallow and lard crystallize in the β' and β forms, respectively (Young, 1985; D'Souza et al., 1990; Enser, 1995). However, similar studies for lamb fat are lacking.

For both separable lean and fat, the major fatty acids in lamb, as in other meats, are 16:0, 18:0 and 18:1. However, lamb/mutton also has more unusual fatty acids, such as positional and geometric (*trans*) isomers of unsaturated acids (Enser et al., 1996) and branched-chain acids (Garton et al., 1972; Wong et al., 1975; Ha and Lindsay, 1990; Brennand and Lindsay, 1992a).

Cholesterol content of lamb, relative to beef and pork, was mentioned in the previous section. With additional meat types included, cholesterol levels (mg/100 g) in descending order would be: veal (83) > chicken leg (80) > duck (77) > turkey dark meat (69) > lamb (65) and pork (65) > beef (60) and turkey light meat (60) > chicken breast (58) for the raw, separable lean (NLSMB, 1988).

Factors Affecting Fatty Acid Composition and Cholesterol Content

Many factors influence the fatty acid composition of lamb, with some fatty acids being affected more than others. Sheep, like other ruminants, are not as responsive to changes in dietary fat as monogastric animals are, because microbial modification of dietary fatty acids occurs in their rumen. Ruminal microorganisms convert much of the ingested unsaturated fatty acids into saturated ones. This is not to say that the composition of diets for ruminants has no effect on fatty acid profiles of animal tissues. Microbially-mediated formation of branched-chain fatty acids from amino acids (Garton, 1977) or from incorporation of methylmalonate (from dietary propionate) into fatty acids (Garton et al., 1972) could also occur in the rumen of sheep. Differences in feeding regimen have been cited as a possible cause of the variation in PUFA composition between domestic and imported lamb; N.Z. lambs are mostly grass-fed/grazing type, while U.S.

lambs are grain-fed/feedlot managed (Lin et al., 1988). Enser (1995) mentioned that grazing may increase the concentration of 18:0 in adipose tissue, while finishing lambs on grain concentrates may increase 18:1, 18:2 and branched-chain fatty acids. Garton et al. (1972) reported that the effects of a high-energy barley diet (basal diet) or a similar diet supplemented with propionate (incorporated at the expense of barley, as 21% of metabolizable energy) increased the proportions (mol/100 mol total fatty acids) of branched-chain and odd-numbered fatty acids in the triglycerides of subcutaneous lamb adipose tissue and decreased the proportion of saturated acids, especially 16:0 and 18:0, when compared to corresponding supplemented diets with acetate or butyrate. The physical nature of feed fat may also affect the extent of rumen hydrogenation of dietary unsaturated fatty acids. Amounts of PUFA in ruminant meats can be increased by feeding animals protected lipid (high-PUFA) supplements (Rhee, 1992; Enser, 1995) that can functionally bypass the rumen. The protective/encapsulating materials used for the lipid supplements should meet the human food safety criteria.

Maturity of the animal also influences the meat fatty acid composition and cholesterol content. Ono et al. (1984) studied lambs from two age groups. Lamb cuts from younger animals (4 to 4.5 months) had higher amounts of 18:2 and 14:0 acids and a higher PUFA/SFA ratio than those from older animals (8 to 9 months). Cholesterol content in the raw lean was slightly higher in some of the cuts from younger animals (72 vs. 66 g/100 g in the foreshank, 67 vs. 64 in leg sirloin). Since cholesterol is a major component of cell membranes, the smaller cell size and greater cell number per unit muscle mass in younger animals may be the cause of this (Lin et al., 1988). Sutherland and Ames (1996) found increased levels of certain medium-length branched-chain fatty acids and several straight-chain fatty acids in both rams and wethers slaughtered at 30 weeks of age as compared to those slaughtered at 12 weeks.

Sex or sex class affects the degree of tissue fatty acid unsaturation as well. The PUFA-to-SFA ratio for subcutaneous fat was higher for rams than for wethers and ram subcutaneous fat had more 14:0 and 18:3 and less 18:0 (Crouse et al., 1972; Kemp et al., 1981). Percentages of 18:3 and 18:2 in intramuscular fat (marbling) were also higher for rams than wethers. Subcutaneous fat of ewes had higher percentages of 18:1 and total unsaturated fatty acids than subcutaneous fat of wethers (Kemp et al., 1981).

Palatability of Lamb as Rated by Consumers

Species-related flavors may influence consumer meat preference or selection. For sheep meat, flavor is frequently considered to be the most important determinant of acceptability. Dislike of the characteristic ovine flavor has been cited or implicated as one of the reasons for low consumption of lamb and mutton (Batcher et al., 1969; Cramer, 1983; Sink and Caporaso, 1977; Jones et al., 1988).

There has been no clear distinction between lamb and mutton flavors, and the concept of mutton flavor may vary among people (Batcher et al., 1969). Cramer (1983) stated that the terms lamb and mutton flavor and odor are used interchangeably and refer to the characteristic flavor of all sheep meat, regardless of age, that many people find undesirable. This review uses "ovine flavor" to refer to this characteristic species-related flavor.

In the study by Rhee and Ziprin (1996) where ground meat patties (raw meat fat content, ~21%) pan-fried at 163°C to an internal temperature of 71°C were used as test samples, the majority of the panelists (a total 71 consumer panelists and 12 experienced panelists) could differentiate lamb from beef and pork in blind taste tests. The possible reasons they provided for this were: 1) lamb inherently has the most intense flavor among the three species (as supported by their study); 2) lamb flavor is unique or more distinct; and 3) lamb flavor is objectionable or unfamiliar and would be easier to detect. They also found that those who could differentiate lamb from beef and pork tended to dislike lamb, more so for those with higher sensory acuity, such as experienced sensory panelists. However, in a comparative study reported by Smith et al. (1974) on palatability of various animal species, two out of five untrained panels (the number of panelists within a panel varying from 21 to 94) liked lamb flavor more than beef flavor (significantly for one panel and numerically for the other one), whereas three panels rated beef flavor higher (significantly for one panel and numerically for the other two). Panelists in their study were served lean samples (longissimus muscle) from bone-in chops or steaks (with 7.5 mm subcutaneous fat) cooked in a 177°C oven to an internal temperature of 75°C.

Young et al. (1994) recommended that ethnic panels be considered when evaluating acceptability and intensity of ovine flavor. Griffin et al. (1992) used a 20-member panel, half of which was composed of natives of mostly developing countries. The panelists from foreign countries gave generally higher ratings for flavor, juiciness, tenderness and overall palatability than the domestic (U.S.) panelists.

Trained Panel Sensory Evaluation

Tenderness of Sheep Meat

Texture and tenderness are secondary to flavor in determining the acceptability of lamb and do not generally constitute a major problem. Thus, no detailed discussion of these attributes will be provided in this review. Many factors that affect texture and tenderness of other red meats may similarly affect lamb. For example, the meat of younger sheep is more tender and has less fibrous tissue residue than that of older animals (Schonfeldt et al., 1993) and there are differences between sex classes, with meat from wethers (the customary type of lamb marketed in the U.S.) being more tender than meat from rams (USDA, 1988).

Flavor Profile of Lamb

The flavor of fresh cooked meat of a given species reflects a blend of general meaty notes common to all meats and flavor notes specifically associated with the species. Many descriptors have been used for the flavors perceived in lamb and mutton. The flavor profile reported by Jeremiah (1988) included such descriptors as "lamb" and "wooly" for aromatics of cooked lamb, with "lamb" being more intense. Hofstrand and Jacobson (1960) made fat-rich and fat-free broths of mutton for experienced panelists to rate. Fat-rich broths were "lamb-like," "sweet," "oily" and "barny," while fat-free broths were more "sour," "salty," "meaty" and "sharp." It is also well known that lamb has a "waxy" (Young et al., 1994) or greasy "mouth-coating" effect and aftertaste (Cross, 1987) due to the nature of the fat. Special attention has been given by researchers to the odor termed "*soo*," the Chinese term for the characteristic flavor of sheep meat meaning "sweaty-sour" (Wong et al., 1975). Ten attributes were selected by trained panelists for cooked lamb flavor in a study by Rousset-Akrim et al. (1997). "Sheepmeat" flavor was the most intense. Some of the other descriptors included "animal," "poultry" and "boiled meat."

Chemistry of Sheep Meat Flavor

Source and Chemical Components of Lamb/Mutton Flavor

The tissue source of cooked ovine flavor has varied among researchers. Some have concluded that the source is adipose tissue (subcutaneous/depot fat), while others have mentioned intramuscular (muscle tissue) lipids. Young et al. (1994) discussed the various studies that support each stance. Their generalization was that fatty tissue (not necessarily lipids per se) is the main source of ovine flavor, although lean tissue undoubtedly makes a contribution.

The chemical compounds that reportedly have been associated with lamb/mutton flavor can be grouped into the neutral, acidic and basic fractions of cooking volatiles, non-volatile flavor compounds, cyclic compounds and sulfur compounds (Cramer, 1983). The neutral fraction of cooking volatiles consists of carbonyl compounds, such as aldehydes, ketones and lactones (Hornstein and Crowe, 1963; Caporaso et al., 1977). The acidic fraction consists of branched-chain fatty acids with 8 to 10 carbons, mainly 4-methyloctanoic, 4-methylnonanoic and 4-ethyloctanoic acids (Wong et al., 1975; Ha and Lindsay, 1990; Brennand and Lindsay, 1992a; Kim et al., 1993) and other medium-chain length unsaturated fatty acids (Wong et al., 1975). The basic fraction of the volatiles involves certain pyridines and pyrazines (Buttery et al., 1977). The non-volatile flavor compounds are sugars, amino acids, nucleotides, phosphates, etc., that contribute more to meaty flavors, rather than to ovine flavor (Cramer, 1983). The cyclic compounds in cooking volatiles include pyridines, pyrazines, thiazoles, alkylphenols and thiophenol (Cramer, 1983; Ha and Lindsay, 1991). The sulfur compounds implicated are hydrogen sulfide (Kunsman and Riley, 1975; Cramer, 1983) and various other sulfur compounds (Cramer, 1983) including 3,6-dimethyl-1,2,4,5-tetrathiane (Nixon et al., 1979). Cramer (1983) hypothesized that sheep could have sulfur stores affiliated with fatty tissue. The hypothesis was based mainly on the following: sheep are the only animals that produce wool (a cystine-rich fiber), the adipose tissues of lamb and beef gave off much larger amounts of hydrogen sulfide than their lean tissues, and lamb samples produced considerably more hydrogen sulfide than beef samples (Kunsman and Riley, 1975). It was theorized that these sulfur stores associated with fatty tissue could then be a source of precursors or compounds contributing to the ovine flavor.

Factors Affecting Sheep Meat Flavor

Age is one of the factors that may influence the intensity of the species-related flavor. It is a general belief that the ovine flavor intensity increases with chronological age (Sink and Caporaso, 1977). It is still not clear, though, if mutton has a significantly different flavor than lamb, or if it merely has an increased flavor intensity. Young et al. (1994) compared and discussed various studies to relate biochemical changes in sheep as they age to lamb and mutton flavors. Results have often been inconsistent or conflicting between studies and sensory evaluation in most of these studies did not specifically address the species-related flavor or odor (Young et al., 1994). To date, whether chemical components associated with mutton flavor is qualitatively and/or quantitatively different than those for lamb flavor has not been conclusively established and needs to be investigated with the breed and feeding/diet backgrounds controlled. Such controlled studies involving a number of sheep breeds would provide more definitive results. Moreover, lamb flavor versus mutton flavor can be better defined and explained if studies aimed at determining the effects of animal age on specific chemical components also include sensory flavor profile analysis (using trained panelists). The most recent studies by Rousset-Akrim et al. (1997) and Young et al. (1997) may serve as a starting point for further analysis on this topic, as discussed later in this section.

Breed and sex apparently have some minor effects on the flavor of sheep meat, possibly due to variations in fatty acid composition, but effects reported are sometimes contradictory (Young et al., 1994). Batcher et al. (1969), who included both age (lamb versus yearling) and sex (wether versus ram) as variables, found no significant differences in flavor scores of cooked meat slices that could be attributed to either variable. However, differences were observed when test samples were ground meat patties with large amounts of fat; patties from wethers were generally higher in flavor intensity than patties from rams, although the inverse is commonly thought to occur. Sutherland and Ames (1996) found consistently higher concentrations of 4-methyloctanoic and 4-methylnonanoic acids in rams compared to wethers, regardless of slaughter age; however, no sensory analysis was conducted. Kemp et al. (1981) found no association between sex and palatability as rated by an experienced sensory panel on a hedonic scale. As for sheep breeds, results varied among studies reviewed by Young et al. (1994); the meat of a fine-wooled breed may be either more "muttony" or not significantly different than the meat of a coarse-wooled breed. This was not the case in the study by Young et al. (1993), where ovine flavor in the lean was significantly weaker in Merino lambs (a fiber breed with very fine wool with a fiber diameter of ~22 µm) than in Coopworth lambs (a combined meat and wool breed with a fiber diameter of ~36 µm). However, the mean pH of the meats also differed considerably, confounding the effects of breed and pH. It was thought that since all the animals were handled identically at slaughter, Merino breed might be prone to high pH condition, the effects of which are discussed later. Crouse et al. (1983), based on their sensory flavor profile data on cooked samples of Suffolk- and Columbia-sired ram or ewe lambs, concluded that breed of lamb does not need to be considered in making production management decisions regarding flavor.

The effects of sheep diets have been extensively studied. Sheep diets may consist of grasses, legumes (white clover, lucerne, vetch), or cereals. Reineccius (1979) and Field et al. (1983) provided detailed reviews of the effects of diets tried in several studies. The main problem with forage feeding/finishing is that the resulting meat usually has a "grassy" flavor, according to Bailey et al. (1994). They reported that the flavor of meat was milder and the concentration of total volatiles was lower when lambs were finished on a corn-based diet than on forage (ryegrass, clover, lucerne). Similarly, "grassy" and "lamby" flavors were less intense when they were finished on grain/oat hay than on alfalfa or sudan grass. Hence, they concluded that grain would be the best diet to reduce such flavors. In line with these, Rousset-Akrim et al. (1997) reported more intense "sheepmeat" flavor for lambs fed a pastoral diet than a grain (corn)-based diet, especially when the growth rate of the animals on the pastoral diet was slow. Garton et al. (1972), however, had shown that a grain-based diet could result in sheep carcasses with unusually soft fat. Off-flavors in the meat are more common in soft and oily fat (Field et al., 1983). Young et al. (1994) concluded in their review that, although meat ftom grain-fed sheep has a different odor and flavor profile, whether the flavor character is capable of reducing or masking "muttoness" to the point of economic advantage is not known.

The ultimate pH (pH at rigor) of meat can affect sheep meat flavor and cooking odor in several ways. This implies that the handling of the animal prior to slaughter can influence the flavor of the resulting meat. Braggins (1996) found that overall cooking odor and flavor intensity were lower at moderate or high pH (6.26 or 6.81) than at more normal post-mortem pH (5.66). Ten odor compounds (mostly aldehydes) out of 54 were responsive to changes in ultimate pH. "Sheepmeat" flavor intensity was higher in the low pH (5.66) meat; the author reasoned that lower pH conditions would favor liberation of branched-chain fatty acids from their parent triacylglycerols. The production of hydrogen sulfide, reportedly making some contribution to ovine flavor (Kunsman and Riley, 1975; Cramer, 1983), may also be affected by meat pH (Johnson and Vickery, 1964). However, unlike the results on "sheepmeat" flavor intensity (Braggins, 1996), more hydrogen sulfide was evolved from meat when muscle pH was high.

Muscle pH was dismissed as a variable in the studies of Young et al. (1997) and Rousset-Akrim et al. (1997). The two studies together have been the most extensive on odor and flavor of lamb; both sensory and chemical analysis were conducted on samples of the same animals and animal treatments involved combinations of several variables. There were seven treatments: six ram treatments (pasture- or grain-fed; slow- or fast-grown; light or heavy finishing weight) and old ewes raised mainly on pasture. Rousset-Akrim et al. (1997) conducted sensory analyses on both meat flavor and fat odor. Both "sheepmeat" odor and flavor were strongest for pasture-fed/slow-grown rams and weakest for grain-fed rams. Old ewes were distinguished only because of "livery" flavor. Extended pasture-feeding (90 vs. 215 days) increased "sheepmeat" odor; however, a male sex effect (older rams being more sexually developed), rather than age effect, could not be excluded. Young et al. (1997) examined the volatile compounds evolved from the rendered fat samples (the fat cooked out from ground meat prepared with lean and fat) which were used by Rousset-Akrim et al. (1997). Their results confirmed that "sheepmeat" odor/flavor is caused by medium-length branched-chain fatty acids (particularly 4-methyloctanoic and 4-methylnonanoic acids). Results also indicated that puberty or age (of rams) caused an increase in 4-methylnonanoic acids. They also concluded, from their chemical data along with the sensory data of Rousset-Akrim et al. (1997), that pasture-derived 3-methylindole (skatole) and alkylphenol(s) may intensify the perception of "sheepmeat" odor/flavor. Sulfur-containing compounds were excluded as the primary cause of the flavor. Breed and carcass weight had no notable effects. Further studies were suggested on the role of puberty and age as an independent factor in the development of ovine flavor compounds in rendered sheep meat fat.

Effects of Cooking or Processing Methods

Amounts of certain flavor compounds and the development of flavors from precursors may be influenced by the extent of cooking. Caporaso and Sink (1978) found that fat or adipose tissue cooked at 163°C had a greater amount of total carbonyls compared to fat melted at 50°C. Alk-2,4-dienals were detected only in samples cooked at 163°C. Brennand and Lindsay (1992b) reported that roasting, frying and boiling mutton all produced amounts of certain volatile branched-chain fatty acids and alkylphenols that could be sufficient to provide distinctive mutton flavor notes. They stated that hydrolysis of fats (releasing volatile branched-chain fatty acids) and thermal degradation of precursor compounds should account for the development of mutton flavor/odor during cooking. The amount of hydrogen sulfide may also increase as cooking progresses, especially in adipose tissues (Kunsman and Riley, 1975).

Additionally, whether lamb cuts are cooked with or without fat cover (external fat layer) could affect ovine flavor intensity of the cooked lean. Lamb chops broiled to an internal temperature of 77°C without subcutaneous fat layer (1/4-inch) and epimysium were rated more intense in "mutton flavor/odor" by a trained sensory panel than those broiled with the external fat (Rhee et al., 1990). This was attributed to a greater loss of moisture in the meat broiled without a layer of fat, leading to the concentration of substances responsible for lamb/mutton flavor.

Certain cooking/preparation practices may have an effect of masking the ovine flavor. An example of such practices is the deliberate seasoning of the meat with various herbs and spices before cooking. Use of rosemary and garlic is especially common (Young et al., 1994). Other seasonings used include thyme, sage, basil, cloves and oregano. These ingredients may not only mask lamb/mutton flavor, but also act as antioxidants, modulating the oxidation reactions that take place during cooking (Young et al., 1994). Jurdi-Haldeman et al. (1987) found that onion or garlic juice decreased lipid oxidation (as determined by 2-thiobarbituric acid reactive substances) in cooked-stored ground lamb containing salt (1% NaCl in raw meat). When sensory evaluations were conducted for the control and onion juice-treated samples using a trained panel, relative oxidative rancidity levels (ratios of magnitude estimation) were not significantly different between the control and treated samples. Numerically, however, the samples with onion juice had consistently lower rancidity levels than the control, regardless of storage temperature or time (0 or 7 days at 4°C or 30 days at -20°C). Also, hedonic scores tended to be higher for the onion juice-treated samples.

Smoke flavor, when sufficiently intense, could also cover up ovine flavor. Additionally, smoking may have antioxidative effects. Phenolic compounds in wood smoke make major contributions to smoke flavor (Maga, 1992). When meat is smoked, it becomes less susceptible to lipid oxidation (Pearson and Tauber, 1984), probably due to the antioxidative effects of many of the phenolic compounds from the wood smoke. Smoked, restructured lean lamb roasts (processed with salt and sodium tripolyphosphate) had relatively high ratings for flavor desirability (mean score, 5.6 on an 8-point scale) as evaluated by a consumer sensory panel (Jones et al., 1988). The study, however, did not specifically evaluate the species-related flavor and did not include unsmoked control (cooked without smoking).

Reduction of the ovine flavor can be achieved with water washing. When lipid extracts from beef, lamb and pork adipose tissues were washed with water, the percentage of sensory panelists who correctly identified the species of heated extracts decreased for lamb and pork, but increased for beef (Wasserman and Spinelli, 1972). When the water-washes were evaluated, only the lamb extract wash was identifiable by its odor. Washing of meat itself can also reduce the characteristic species-related flavor. When ground mutton containing 4.16, 9.84 or 18.90% fat was washed with high-pH (8.2) tap water, the intensity of species flavor in cooked samples was rated "very weak" by a trained sensory panel (Rhee et al., 1998). Experiments conducted with ground lamb indicated that water washing can sharply decrease total fat content, lipid oxidation potential and amounts of volatile branched-chain fatty acids (Rhee et al., 1998).

Another approach evaluated is using lamb and mutton with nonmeat food materials in the development of new products through processes conducive to flavor alteration.

Extrusion cooking was a process that can chemically and physically modify food ingredients by subjecting them to high temperatures and pressures in combination with the action of shearing forces (Andersson, 1984). Cho (1996) compared expanded extrudates from blends of starch and various meats (lamb, mutton, spent hen meat, goat meat, beef). When evaluated by a trained panel, all the extruded products containing different types of meat were not significantly different in various flavor attributes (aromatics). Moreover, extrudates containing lamb, mutton or goat meat were less susceptible to lipid oxidation than other products during accelerated storage at 37°C over 150 days. It is not known whether any compounds responsible for, or contributing to, the species-specific flavors of these meats or their decomposition products, or compounds resulting from their interactions with certain constituents of the nonmeat materials used could have had antioxidative effects.

When defatted soy flour was used in addition to starch and meat (lamb, beef or pork; Rhee et al., 1997), extrudates with lamb exhibited less lipid oxidation than those with beef and the difference was not related to product fat content. Comments made by trained panelists to describe "very weak" off-flavors detected in the extrudates indicated that the off-flavors might have been due to flavors of defatted soy flour, not any meat species-related flavors. Extrusion cooking of sheep meat with nonmeat ingredients could reduce the ovine flavor by dilution and possibly by volatilization when the cooked mixture exits the extruder at a high temperature with instantaneous puffing. Also, certain chemical reactions (e.g., between sheep meat proteins/amino acids and starch hydrolysis products) may take place, giving rise to more desirable flavors.

Flavor of Stored Sheep Meat

The oxidation of unsaturated fatty acids are primarily responsible for oxidative meat flavor deterioration (Rhee, 1992). Meats contain substances that catalyze lipid oxidation, such as enzyme systems (for raw meat only), nonheme iron and heme iron (mainly myoglobin), and cooking will increase their susceptibility to oxidation (Rhee, 1992). The extent to which stored sheep meat is oxidized will depend on the combination of all these factors and also storage conditions such as temperature and exposure to oxygen. In addition to lipid oxidation, changes in meat proteins and peptides may be partly responsible for flavor deterioration in cooked-stored meat, as documented for beef (Spanier et al., 1988).

As mentioned previously, it had been suggested that carbonyl compounds from lipid oxidation may be responsible for flavor/odor differences among meats of different animal species (Cross and Ziegler, 1965; Rubin and Shahidi, 1988). Thus, some studies have focused on documenting whether minimizing lipid oxidation in stored sheep meat would reduce ovine flavor. Available data indicate the opposite. Cho and Rhee (1997) studied the effects of several additives (sodium ascorbate, lactate, nitrite and tripolyphosphate, and propyl gallate) on the flavor of cooked, ground mutton (10% fat in raw meat) stored at 4°C for up to 4 days. The species flavor was more intense in nitrite-treated samples where the least lipid oxidation had occurred. Overall, species flavor intensity scores were negatively correlated with lipid oxidation measured by 2-thiobarbituric acid reactive substances ($r = -0.58$; $P < 0.001$).

In the study by Reid et al. (1993), sensory panelists were able to differentiate mutton lean tissue cured with nitrite from corresponding beef, pork or chicken samples. Their study also included anoxic versus aerobic cooking and storage (5 days at 0°C) of both lean and fat samples. "Mutton" odor intensity was not different between anoxic and aerobic samples for the lean; for the fat, however, it was more intense in anoxic samples. Curing combined with anoxic cooking and storage of fat also was not effective in reducing mutton odor intensity.

Results of these studies do not support the previous hypothesis that uncured, cooked meat flavors with species differentiation may be largely due to volatile lipid oxidation products (Cross and Ziegler, 1965; Rubin and Shahidi, 1988). However, lipid oxidation may indirectly influence the intensity of the ovine flavor. The mechanism is not clear. Our hypothesis is that some of the compounds responsible for or contributing to (or intensifying) the ovine flavor may be altered or degraded when cooked and stored aerobically without added antioxidative substances, whereas they may remain unaffected or less affected when lipid oxidation is controlled. An underlying assumption for this hypothesis is that free radicals produced from lipid oxidation may directly or indirectly affect compounds related to the ovine flavor.

Conclusions

Aside from decreasing total carcass fat, which is already being done for all meats, nutrient profiles of lamb do not present the foremost problem in its marketability or acceptability; flavor remains the main concern. It has been difficult to make definite conclusions regarding which compounds may be responsible for the ovine flavor (and to what extent) – until the studies by Rousset-Akrim et al. (1997) and Young et al. (1997) – and what specific effects animal diet, sex, age or breed may have on the species flavor. This is because experimental protocols and procedures (e.g., sample preparation and sensory analysis procedures) were not standardized among studies. Obviously, a combination of factors influence the ovine flavor and interactions most likely exist among such factors. More definitive studies are needed regarding puberty and age effects, as well as sex effects, and further studies are required to conclusively determine interactive effects of all the variables that influence the ovine flavor. Ideally, each of such studies should use experimental approaches and procedures that would allow for meaningful comparisons of sensory and chemical analyses results, as in the well-coordinated studies of Rousset-Akrim et al. (1997) and Young et al. (1997). Further studies also are needed to elucidate the mechanisms by which the chemical compounds responsible for or intensify the ovine flavor are formed. Then, genetic manipulation would be the next logical step to modulate the species flavor. In the meantime, innovative processing methods should be explored further in order to increase the utilization and consumer acceptance of lamb and mutton.

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Methodology for Identification of Lamb Carcass Composition[1]

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Introduction

Lamb procurement in the United States has historically been based on live weight, dressing percent and pelt characteristics. The national average slaughter weight for lambs has increased sharply over the last decade (American Sheep Industry, Inc. [ASI], 1996). Dressing percent is largely a function of carcass fat content. As carcasses become fatter, the dressing percent increases.

The procurement of lambs based on increasingly heavier weights and a high dressing percent has encouraged the production of lambs with high amounts of carcass fat. Couple this with economical feedstuffs and seasonal lamb supplies, one should not be surprised that one of the largest problems facing the U.S. sheep industry is the production of excess fat at the front end of the marketing chain (Magagna, 1991; Texas Agricultural Marketing Research Center [TAMRC], 1991; Tatum et al., 1992). A logical starting place to send clearer signals to producers regarding market preferences and improve consumer perception of lamb would be to modify the method of lamb procurement from one based on live weight and dressing percent to one based on salable lean tissue, carcass composition and/or yield of consumer desired retail cuts.

Accurate cutability classification of lamb carcasses would be a means for identifying differences in carcass value. Carcass procurement based on lean yield would be a strong deterrent to marketing over-finished lambs. A carcass yield pricing system must have an acceptable level of accuracy in carcass evaluation such that it receives producer confidence and packer acceptance.

This review addresses technology that has shown potential under laboratory or industrial conditions to identify lamb carcass composition, primal cut composition or retail yield. This includes the use of carcass or live weight, the USDA yield grading system, ultrasonic scanning, optical reflectance probes, bioelectrical impedance and electromagnetic scanning of whole carcasses.

Key words: lamb, carcass composition, lamb marketing, instrument grading.

Assessment of Carcass Composition using Linear Measures, Subjective Scores and Weight

Influence of Live and Carcass Weight on Assessment of Carcass Composition

Live weight (LWT) and projected carcass weight (CWT) are selection criteria that are easily obtained and often used as the deciding factor for delivery of lambs to slaughter and as the basis for value. Live weight can be used effectively to predict carcass composition when genotype, nutritional management and sex are similar within a given population across a range of weights. Wishmeyer et al. (1996) reported correlation coefficients of 0.96, 0.86 and 0.80 for LWT to whole body fat free soft tissue, ether-extractable fat and crude protein, respectively, for Rambouillet wethers ranging from 29.5 to 63.0 kg live weight. Snowder et al. (1994a) found that slaughter weight had moderately high correlations with measures of carcass fat (backfat, $r = 0.60$; percentage of carcass fat, $r = 0.63$) and negative correlations with measures of carcass lean (percentage of carcass protein, $r = -0.55$; percentage of carcass moisture, $r = -0.63$). Berg et al. (1994b) reported CWT had a high correlation to total dissected lean (TDL; $r = 0.92$) and carcass fat ($r = 0.87$), while Berg et al. (1996) found LWT to have highly significant correlations with weight of carcass TDL

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and weight of carcass fat free lean (FFL). Jenkins et al. (1988) reported that CWT accounted for 91% of the variation as a predictor of fat free soft tissue (FFST) and Slanger et al. (1994) reported that CWT was a reliable predictor of the total weight of retail-ready cuts ($R^2 = 0.88$). A survey of over 6,000 lamb carcasses by Tatum et al. (1988) found that increased CWT was highly associated with increased carcass fatness. Furthermore, Garret et al. (1992) found that yield grade 3 (YG-3) and YG-4 carcasses were significantly heavier than YG-2 carcasses.

Lamb LWT and CWT can be used to explain a moderate to high amount of the variation of weight of TDL, FFL, dissected carcass fat and composition of the whole body. Prediction of proportional yield of TDL, FFL and carcass fat by LWT or CWT is less accurate. By expressing carcass lean or fat as a proportion of CWT, carcass weight becomes standardized within the dependent variable, thus, the amount of variation explained by CWT as an independent variable is minimized. Berg et al. (1996 and 1997) reported that correlations between lamb LWT and CWT to percentage of boneless closely trimmed primal cuts (%BCTPC), percentage of TDL (%TDL) and percent FFL (%FFL) were small and insignificant. Garret et al. (1990 and 1992) reported that prerigor CWT was an insignificant predictor of percentage of retail cuts agreeing with Edwards et al. (1989) who found that LWT and CWT were poor predictors of salable carcass yield.

Lambs of different genotypes can have different carcass composition at similar LWT (Lehmkuhler et al., 1997; Snowder et al., 1994a; Meyer et al., 1993). Breeds possessing different growth rates or mature size that are slaughtered at a constant weight will generate carcasses with a wide variation in composition (Snowder et al., 1994a). Baird et al. (1989) reported that lambs of different frame sizes slaughtered at a constant end weight possessed different YG. Fritz et al. (1995) found Suffolk lambs to have a lower percentage of total and internal fat and a higher percent of carcass lean than Rambouillet or fine-wool crosses. Snowder et al. (1994a) reported that Columbia sired wethers had less carcass fat than Targhee-, Polypay- and Rambouillet-sired wethers of similar weight. Leymaster and Jenkins (1993) reported different carcass lean and fat accretion rates between Suffolk- and Texel-sired lambs of similar carcass weight. The recent identification of sheep possessing the heavy muscled, callipyge genotype (Jackson et al., 1997) highlights the potential bias of over-reliance on LWT or CWT as a predictor of carcass composition without accounting for breed or genetic differences.

Lamb LWT and projected CWT have long been used as a primary criteria in procurement of market lambs and is most likely ingrained in the U.S. lamb marketing system. Lamb LWT or CWT can account for a high percentage of the variation for carcass component mass in a prediction equation, particularly when the range of weights of the specific population sampled is broad. However, LWT or CWT alone will not accurately account for compositional differences between individual animals or groups of animals (lines, crosses) that differ in lean muscle mass at similar live weight. Gu et al. (1992) reported that the most precise and least biased prediction equations for estimating pork carcass composition contained a measure of weight, muscle mass and carcass fatness.

Linear Measures, Subjective Scores and Conformation to Assess Cutability

The USDA yield grade system is based on a numerical score of 1 to 5, estimating the percent yield of boneless, closely trimmed retail cuts (%BCTRC) from the leg, loin, rack and shoulder (USDA, 1992). A lower YG number indicates a higher yield of %BCTRC. Factors influencing the %BCTRC are: carcass muscle mass, carcass weight, internal fat, subcutaneous fat and intermuscular (seam) fat. Current cutability grades used by the three red meat species (beef, pork, lamb) incorporate one or more of these criteria to establish the numeric value associated with retail yield (Table 1).

Both beef and pork include cutability criteria associated with muscling and trimmable fat. Pork carcass cutability is calculated from a subcutaneous backfat thickness and subjectively estimated carcass muscling (conformation). Estimating beef carcass retail yield incorporates carcass weight, estimated carcass muscle mass, subcutaneous fat and internal fat as evaluation criteria. The lamb carcass cutability grade is the only one of the three red meat species that does not account for muscling as an evaluation criterion.

Prior to July of 1992, the determination of YG by processors was voluntary. It is now mandatory that any lamb carcass receiving a quality grade must also be assigned a YG (USDA, 1992). Current calculation of lamb YG consists of a single measure of fat depth taken over the center of the longissimus muscle at the $12^{th}/13^{th}$ rib interface. Under industrial condi-

Table 1. A comparison of cutability grade criteria for beef, pork and lamb carcasses.[a]

Measurement	Beef	Pork	Lamb
Size	carcass weight	none	none
Muscling	ribeye are	muscle score	none
Trimmable fat	12^{th} rib fat thickness	last rib backfat	12^{th} rib fat thickness
Internal fat	kidney, pelvic and heart fat	none	none

[a] Adapted from Savell (1997).

tions, however, the determination of lamb YG is done by trained USDA graders that use a subjective visual estimate of the fat depth over the longissimus muscle, adjacent to the 12th rib. The YG can be adjusted for bodywall (BW) tissue thickness and other indications of carcass fat distribution representative of specific YG.

Classification of lambs by YG, fat depth and fat distribution can be useful as fat can account for much of the variation in lamb cutability (Harris et al., 1990). Fritz et al. (1995) found that total carcass fat content increased as YG increased. Field et al (1963) reported that fat thickness over the longissimus muscle had a correlation coefficient of -0.57 to percent of carcass lean. Carpenter et al. (1964) found that fat thickness over the ribeye was highly correlated to percent fat trim of a carcass and had a high negative correlation to carcass retail value. Garret et al. (1990) reported that lamb carcass fatness had the greatest influence on retail yield. A recent study by Berg et al. (1997) found 12th rib fat depth was more highly correlated ($r = -0.50$) to %BCTPC than warm CWT ($r = -0.14$) or ribeye area ($r = 0.29$).

The use of a single fat depth criteria as a means to assign carcasses a numerical YG can lead to misclassification of carcasses relative to retail yield, particularly when a subjective visual estimate is used. Heaton et al. (1993) reported that visual estimation of the single point fat parameter was, at best, a marginal predictor of lamb carcass composition even when the most experienced lamb carcass evaluators were used. An Australian study by Cabassi (1990) compared the use of the GR measure (total tissue thickness adjacent the 12th rib, 11 cm lateral the carcass midline), the AUS-Meat sheep (optical reflectance) probe and a subjective fat score by a trained Australian grader. Subjective fat scores were the least precise predictors of percentage of dissectable fat. Cabassi (1990) concluded that the use of graders and subjective systems resulted in errors associated with grader consistency and an increased variation between graders that could be overcome by a more objective system of carcass classification. Jones et al. (1992) reported that the visual classification of Canadian carcass cutability grade was a poor estimate of the lean content of fatter carcasses. Snowder et al. (1994b) reported that backfat depth accounted for only 21 and 22% of the variation in the percentage yield of major and total retail cuts, respectively, under commercial conditions. The authors further reported that BW measurement of tissue depth accounted for 30% more of the variability for yield of retail cuts as compared to the use of the backfat depth over the ribeye.

The use of a single measure of subcutaneous fat depth over the ribeye does not account for different distributions of adipose tissue throughout the carcass. Leymaster and Jenkins (1993) reported that Suffolk-sired lambs had significantly more total carcass fat at 147 and 189 days than Texel-sired lambs, but the Texel-sired lambs had a greater fat depth at the 12th rib. Field et al. (1993) found breed differences in carcass seam fat. The group concluded that incorporation of this information into YG system would more accurately reflect consumer preference. A market basket survey of lamb conducted by Harris et al. (1990) found that little external fat remained on retail cuts displayed in the meat case and a large percentage of the fat remaining in the cut was seam fat.

The use of a fat depth measure can have increased accuracy and precision by incorporating other measures in the prediction equation. Berg et al. (1997) investigated ultrasound, electromagnetic scanning, bioelectrical impedance, optical probes and the use of linear carcass measures to predict carcass composition. Warm CWT, ribeye area and BW thickness when combined with an external fat depth measurement predicted %BCTPC

Table 2. Coefficients for predicting lamb carcass composition from traditional carcass measurements.[a]

Item[b]	%BCTPC (N = 106)[c]	TDL, kg (N = 106)[c]	%TDL (N = 106)[c]	FFL, kg (N = 101)[c]	%FFL (N = 101)[c]
Intercept	46.41	0.694	51.60	0.241	46.11
Prerigor carcass weight, kg	-0.174 (0.0183, 0.06)	0.450 (0.6001, 0.0001)	-0.179 (0.0073, 0.1089)	0.471 (0.0738, 0.0001)	-0.331 (0.026, 0.006)
Fat depth, mm	-0.12 (0.2514, 0.0001)	-0.182 (0.1984, 0.0001)	-0.592 (0.5678, 0.0001)	-0.112 (0.0065, 0.0381)	-0.829 (0.5499, 0.0001)
Loin muscle area, cm^2	0.825 (0.1466, 0.0001)	0.243 (0.0284, 0.0001)	0.913 (0.0564, 0.0002)	0.238 (0.5708, 0.0001)	1.26 (0.0883, 0.0001)
Bodywall thickness, mm	0.154 (0.0735, 0.0003)	-0.183 (0.0319, 0.0001)	-0.283 (0.0869, 0.0001)	-0.143 (0.2072, 0.0001)	-0.152 (0.0361, 0.0019)
R^2, RSME[c]	0.490, 2.11	0.859, 0.778	0.718, 2.55	0.858, 0.751	0.700, 2.82

[a] Reprinted from Berg et al., 1997.

[b] %BCTPC = weight of boneless, closely trimmed primal cuts/warm carcass weight; TDL = total dissected carcass lean weight; %TDL = TDL/warm carcass weight; FFL = TDL - weight of chemically derived fat; %FFL = FFL/warm carcass weight.

[c] Partial R^2 and P-value of test that true coefficient value is zero, reported respectively, in parentheses.

better than any technology tested with the exception of the optical grading probe measurement of chilled carcasses (Table 2). However, acquisition of these linear measurements would not be practical in a commercial setting as lamb carcasses are not traditionally ribbed and manual collection of these data points would be very labor intensive. Electromagnetic scanning of warm carcasses provided the only equations superior to those derived from linear carcass measures for %TDL, TDL, %FFL and FFL.

Carcass conformation scores have been used to classify lamb carcasses as to potential muscle mass. The leg conformation score as a criteria in determining YG was discontinued when the YG changes were made in 1992. Some European systems of lamb grading continue to use conformation scores as a part of carcass classification schemes. The use of a subjective conformation score to predict carcass muscle mass can be confounded with carcass fatness (Tatum et al., 1988). Carcasses with more fat tend to have more desirable conformation scores. Purchas and Wilkinson (1995) found that carcasses possessing an E conformation (E-U-R-O-P; in order of decreased conformation) had a higher proportion of leg when adjustments for packing plant, sex, CWT, GR depth and backfat depth were made. Purchas and Wilkinson (1995) admitted that this "may not represent the real situation" and actually discovered that carcasses with superior shape proved to have lower lean yield as a result of higher external fat levels. Hopkins et al. (1994) stated that conformation may influence the appearance of particular retail cuts. As a predictor of carcass yield, however, it has little value. Purchas and Wilkinson (1995) and Harris et al. (1990) agree that the primary value of carcass conformation would be that superior conformation produces thicker muscle cross sections and retail cut shapes that consumers find more aesthetically pleasing.

Ramsey et al. (1991) contend that percentage of fat and protein in a lamb carcass are more accurate measures of true carcass composition and value than percentage of closely-trimmed retail cuts. By estimating trimmed retail cuts, the industry is giving the advantage to fatter carcasses as a large percentage of the remaining fat is intermuscular (seam) fat (Harris et al., 1990). The only way to reduce the fatness of market lambs produced in the U.S. is to identify and price lean lamb accordingly. The use of a single subjective measure of carcass fatness is the current criteria used to assess lamb carcass composition in the U.S. It is a procedure that is familiar to the industry, the industry has the infrastructure and trained personnel to generate the data and the procedure is fast and noninvasive. The U.S. sheep industry will have to decide if the YG system is accurate and precise enough to develop a carcass merit pricing system based upon it.

Electronic Technology for Assessment of Lamb Composition

Savell and Cross (1991) reported that cattle producers' reluctance to sell beef in a carcass merit system stemmed from the use of humans for grading. The grading system must operate in a manner that would be consistent and uniform over time and throughout the country (Sim, 1983). True value-based marketing will not be accepted by producers unless carcass value is determined via objective mechanical instrumentation (Cross and Belk, 1994).

Reviews have been published of potential technologies to objectively determine live or carcass composition (Jones, 1992; Forrest et al., 1989; Topel and Kauffman, 1988) or carcass value (Boland et al., 1995a,b; Akridge et al., 1992). The transfer of technology from the laboratory to an industrial application within an industry that is rooted in tradition and has relied on subjective visual appraisal for evaluation and grading of live animals and carcasses for the last 50 years will require a major adjustment in philosophy (Forrest and Judge, 1994).

Scientific evaluation of a potential grading technology is often too concerned with equipment *accuracy* and neglects the operational needs the packing plant will require for practicality and efficiency. Sim (1983) stated, "The bottom line is productivity." Therefore, a particular piece of equipment has no chance of incorporation into an integrated on-line system if it slows line speed, has the potential to produce more "down time," requires additional personnel or necessitates extra time for operation. Electronic technology has little chance for on-line application if it does not generate monetary gain by replacing plant personnel, improving carcass classification or by more accurately pricing carcasses relative to yield of salable lean. Some of the more "industry friendly" technologies that have potential for on-line practicality and efficiency in a fully integrated, value-based marketing program are light reflectance probes, ultrasound, electromagnetic scanning and bioelectrical impedance. Table 3 summarizes current research publications addressing the use of electronic technologies for the evaluation of lamb carcass composition.

Table 3 and much of the discussion in the remainder of this article report R^2 values for prediction equations that incorporate differing independent variables to evaluate the accuracy and precision of various technologies in estimating lamb carcass composition. The majority of the prediction equations reported in the literature for BIA, EM scanning and ultrasound contain either LWT or CWT as an independent variable. Often, LWT or CWT account for 80% or more of the variation in a prediction equation, especially when the independent variable is a measure of carcass component mass and not a proportional measure (see previous discussion on live and carcass weight). The larger the variability of LWT or CWT of a population of animals in a specific trial, the higher the R^2 between carcass component mass and LWT or CWT.

Gu et al. (1992) discussed the limitations of comparing the R^2 values of prediction equations obtained from differing research reports that estimated carcass composition of swine.

Table 3. Review of electronic technology used for the prediction of lamb carcass composition.

Investigator, year	Medium (N)	Dependent variables	Independent variables	R^2
Bioelectrical Impedance Analysis:				
Cosgrove et al., 1988	chilled carcass (10)	dissected lean	Side wt., RS (3X), side wt./RS (3X)	0.95
	chilled carcass (10)	dissected fat	Side wt., Z, length^2	0.97
Jenkins et al., 1988	chilled carcass (40)	fat-free soft tissues	Chilled CWT, length^2/RS	0.95
Slanger et al., 1994	live (58)	retail-ready cuts	LWT, RS, length	0.79
	chilled carcass (54)	retail-ready cuts	CWT, RS, XC, length, carcass temp.	0.97
Berg & Marchello, 1994	live (98)	fat-free mass	LWT, RS, XC	0.77
	live (98)	fat-free soft tissue	LWT, RS, XC, length	0.79
	hot carcass (98)	fat-free soft tissue	HCWT, RS, XC, length, temp.	0.79
	chilled carcass (98)	fat-free mass	CWT, RS, XC, length, temp.	0.78
Berg et al., 1996	live (101)	dissected lean	LWT, RS, XC, length	0.67
	live (96)	fat-free lean	LWT, RS, XC, length	0.69
Berg et al., 1997	chilled carcass (106)	dissected lean	HCWT, RS, XC, temp.	0.81
	chilled carcass (101)	fat-free lean	HCWT, RS, XC, temp.	0.78
Electromagnetic Scanning:				
Berg et al., 1994[a]	hot carcass (21)	dissected lean	HCWT, length, $TOBEC_D$	0.98
	hot carcass (21)	dissected leg lean	HCWT, $TOBEC_D$, $TOBEC_D$	0.95
	hot carcass (21)	% dissected lean	CWT, PEAK, $TOBEC_D$, length	0.79
Wishmeyer et al., 1996[b]	live – fed (47)	fat-free soft tissue	LWT, P2T, heart girth	0.94
	live – unfed (47)	fat-free soft tissue	LWT, length, PEAK, P1R, P2T, heart girth	0.96
Berg et al., 1997	hot carcass (96)	fat-free lean	PEAK, $TOBEC_D$, $TOBEC_D$	0.88
	hot carcass (101)	dissected leg lean	HCWT, $TOBEC_D$, $TOBEC_D$	0.84
	hot carcass (101)	dissected loin lean	HCWT, $TOBEC_D$, $TOBEC_D$, $TOBEC_A$	0.59
	hot carcass (101)	dissected rib rack lean	PEAK, $TOBEC_A$	0.56
	hot carcass (101)	dissected shoulder lean	HCWT, $TOBEC_D$, $TOBEC_A$	0.59
	chilled carcass (96)	fat-free lean	CWT, $TOBEC_A$, $TOBEC_A$, $TOBEC_D$	0.82
Optical Reflectance Probe:				
Cabassi et al., 1990	chilled carcass (50)	% dissected fat	ASP-GR	0.77
Ramsey et al., 1991	hot carcass (147)	% chemical carcass fat	GP depth at GR, KPH%	0.76
	hot carcass (147)	% chemical carcass protein	KPH%, probe-GR, leg conformation score	0.64
Jones et al., 1992	chilled carcass (1,666)	dissected lean	GP 12th rib FD, GP 12th rib MD	0.68
	chilled carcass (1,666)	dissected fat	GP 12th rib FD, GP 12th rib MD	0.58
Garret et al., 1992	chilled carcass (165)	tray-ready cuts,0.25-mm trim	Hennessy GP-GR	0.48
Hopkins et al., 1995	chilled carcass (607)	ruler measured GR depth	ASP-GR	0.80
Berg et al., 1997	hot carcass (54)	dissected lean	HCWT, GP 6-cm FD, GP 6-cm TD	0.72
	hot carcass (54)	fat-free lean	HCWT, GP 6-cm FD, GP 6-cm TD	0.67
Ultrasound:				
Edwards et al., 1989	live (30)	mod. retail cuts, 0.25-mm trim	Visual FD, ultrasonic FD, ultrasonic REA	0.57
Ramsey et al., 1991	live (147)	% chemical carcass fat	LWT, ultrasonic GR	0.66
	live (147)	% chemical carcass protein	LWT, ultrasonic GR	0.51
Berg et al., 1996	live (79)	dissected lean	LWT, ultrasonic FD, ultrasonic MD	0.54
	live (78)	fat-free lean	LWT, ultrasonic FD, ultrasonic MD	0.49
Berg et al., 1997	hot carcass (72)	dissected lean	HCWT, ultrasonic FD	0.48
	hot carcass (72)	fat-free lean	HCWT, ultrasonic FD	0.41

Abbreviation key:
ASP-GR = AUS-sheep probe depth at the GR site;
CWT = carcass weight;
FD = fat depth;
GR = total tissue thickness obtained at the 12th/13th rib interface, 11 cm from the midline;
GP = grading probe;
HCWT = prerigor carcass weight;
KPH% = percentage kidney, heart, pelvic fat;
LWT = live weight;
MD = muscle depth;
P1R = first-order (sine) Fourier transformation;
P2T = second-order (cosine) Fourier transformation;
PEAK = the point (or peak) of maximum energy absorption of the electromagnetic scan curve;
REA = ribeye area;
RS = resistance;
TD = tissue depth;
$TOBEC_D$ = the difference between two Total Body Electrical Conductivity points on the electromagnetic scan curve;
$TOBEC_A$ = the area under two Total Body Electrical Conductivity points on the electromagnetic scan curve;
XC = reactance; and
Z = impedance.

Gu et al. (1992) reported that regression models estimating swine carcass composition can be sensitive to changes in the population of pigs sampled and that applying existing equations to animals differing in genotypes could easily result in significant biases and incorrect evaluation. Several conclusions can be drawn from the research of Gu et al. (1992) with swine that have potential implications to the development of a lamb carcass component pricing system. They are: 1) it is difficult to accurately compare prediction equations within or between carcass evaluation technologies that utilized different populations of animals; 2) any industrial application of carcass evaluation techniques that have been researched in the laboratory will need further refinement of equations in the field; and 3) prediction equations that are developed for industrial use will either have to be plant specific or robust (low bias) enough to use across a wide range of lamb types.

Optical Fat/Lean (Reflectance) Probes

The U.S. pork industry has used electronic technology for grading, evaluation and pricing of carcasses for more than a decade. The most widely used electronic evaluation system is the optical fat/lean (or reflectance, or grading) probe. The technology behind the optical grading probe (OGP) exploits the principle that white fat will reflect more light than the darker pigment of lean. The general design of all probes is similar, consisting of a stainless steel tube fitted with a light emitting diode (LED) followed in series by a photo diode (light detector). The LED emits a monochromatic infrared light and the photo diode detects the difference in reflectance between the fat and lean tissues. This allows the probe to distinguish between the two tissues and report a fat and lean (loin muscle) depth. The high correlation between OGP derived fat tissue depth and actual fat depth ($r = 0.92$; Berg et al.,1994a) is the reason these probes are accepted for pork carcass grading as fat thickness is strongly related to dissected fat ($r = 0.83$; Berg et al., 1994a) or percentage lean ($r = -0.77$; Berg et al.,1994a) of pork carcasses. Fat and muscle tissue depths are used as variables in prediction equations to estimate carcass yield (most often percentage of carcass lean) and value. Carcasses with a higher or lower percentage of lean relative to a pre-established base (i.e., 50% lean) receive a premium or discount to the "bid" carcass price. Optical probes are less applicable for estimation of lamb or beef carcass cutability as subcutaneous fat depth is not as closely related to carcass composition. Also, measurement error may occur as fat tissue is quite often removed from the probe site as a result of hide removal.

The Hennessy Grading Probe (HGP, Hennessy Grading Systems; Auckland, New Zealand), adapted for use on lamb carcasses, has been studied as a means of estimating lamb carcass cutability (Berg et al., 1997; Garret et al., 1992; Jones et al., 1992). Garret et al. (1992) reported that hot carcasses probed for fat tissue depth between the 12th and 13th rib, 3.8 cm from the backbone could predict 48% (RMSE = 1.74%) of the variability of percentage of tray-ready retail cuts trimmed to 0.25 cm external fat. This was similar to the findings of Berg et al. (1997) who reported fat and muscle tissue depths obtained on chilled carcasses accounted for 49% of the variation in percentage of boneless, closely trimmed primal cuts. Jones et al. (1992) probed hot and cold carcasses between the 10th and 11th and the 12th and 13th ribs at a position 2.5 cm from the carcass midline. Chilled carcass probes of fat and muscle depth adjacent the 12th rib accounted for 58 and 68% of the variation in dissected lean and fat, respectively. The addition of fat and muscle depth from the 10th/11th rib interface accounted for an additional 6% of the variance for dissected lean and 5% more of the variance in dissected fat. Kempster et al. (1985) reported that additional probe sites increased the accuracy of pork carcass lean prediction, however, Jones et al. (1992) reported it doubtful that this small increase in precision would justify the time necessary to obtain a second measurement under industrial conditions.

Snowder et al. (1994b) found that under commercial conditions, BW thickness was a better measure than backfat over the ribeye for estimating percentage of retail yield. BW had a higher repeatability of measurement between experienced graders, a lower coefficient of variation and accounted for more variation in percentage yield of retail cuts (0.22 vs. 0.34 for BW and fat thickness [FT], respectively). Other countries have used the technology of the OGP for determining an objective measure of carcass BW thickness. In Australia and New Zealand, lamb carcass fatness is described as a fat score (1 = leanest through 5 = fattest) based on total tissue depth taken over the 12th rib, 11 cm from the medial plane (the GR site). Fat scores are assessed by a graders visual appraisal and palpation or by the use of a sharpened metal ruler commonly referred to as a GR knife. The GR measurement is not an official means of lamb grading in Australia but more of a specification, as carcasses are not placed into classes based on value. The market may use this information to set prices or it may not (Hopkins, personal communication).

A number of Australian abattoirs are using the optical AUS-MEAT sheep probe (ASP; Hennessy Grading Systems, Auckland, New Zealand) for measuring tissue depth at the GR site. Hopkins et al. (1995) reported that ASP derived GR was highly correlated ($r = 0.89$) to manual GR. Cabassi (1990) found that manual GR measurement (via GR knife), ASP-GR, caliper measurement of GR and visual fat score explained 80, 77, 83 and 74% of the variation (RMSE = 2.25, 2.14, 2.07 and 2.55%, respectively) in the percentage of dissected carcass fat, respectively. Ramsey et al. (1991) reported OGP derived BW thickness more accurately predicted percentage of carcass fat ($r = 0.80$) and protein ($r = -0.70$) than USDA yield grade (old standard; $r = 0.69$ and -0.61, respectively).

Optical grading probes possess several advantages in an on-line industrial setting. The probe system is simple to operate, relatively inexpensive and can assess carcass composition at rapid line speeds (1000+ carcasses per hour). Hopkins et al. (1995) reported the greatest limitation of the ASP system was the use of a human operator. Boland et al. (1995c) found operator error to significantly affect estimation of pork carcass value. The error could be even greater if optical probes are used to establish lamb carcass value. Ramsey et al. (1991) found that a 1-mm increase in BW thickness increased carcass fat percentage 0.92%. Hopkins et al. (1995) reported that the average ASP measured GR was larger than the manual measurement (GR knife) even when manual measurement was done in the same hole used by the ASP. Cabassi (1990) theorized that if the ASP were incorporated for industrial measurement of GR in the Australian system, it would be used to classify lamb carcasses into fat score categories until the meat marketing system was prepared to accommodate a single millimeter measurement of fat thickness and carcass weight as the two major determinants of price. Hopkins et al. (1995) did concede that an operator with adequate and ongoing training could attain a high level of accuracy.

Ultrasound

Due to the high heritability of carcass traits, there has been a great deal of research regarding ultrasonic prediction of muscle area and subcutaneous fat thickness of live meat animals (for a review see Houghton and Turlington, 1992). Recent advancements in real-time ultrasonic technology in the medical community and improved computer systems have increased the interest in ultrasonic applications for genetic improvement. Johnson et al. (1993) reported that ultrasonic measurement of beef longissimus muscle area (LMA) and FT were highly heritable. They concluded that selection based on age-constant yearling ultrasonic LMA had the potential to increase LMA of progeny by 1.06 cm^2, and selection for age-constant ultrasonic FT could decrease progeny FT by 0.005 cm. Ultrasound has had greater success for prediction of swine carcass traits due to anatomical differences between pigs, beef and lamb (Wilson, 1992). Subcutaneous fat comprises most of the total fat in pigs and has a higher negative correlation to total lean than it does in beef and lamb. The dermal layer is such on swine that it allows for greater acoustical contact of the transducer head. The amount of wool on sheep, hair on cattle and thickness of the pelt or hide will affect ultrasonic transmission and can cause image interpretation error (Houghton and Turlington, 1992). Measurements of ultrasonic LMA or FT have been criticized for subjective interpretation of ultrasonic images. Robinson et al. (1992) reported interpretation of ultrasonic images of FT on potential breeding animals can be measured nearly as accurately as on the carcass and a very experienced sonographer measures LMA only slightly less accurately than it can be measured on a carcass. Walder et al. (1991) concluded that increased level of operator skill showed no improvement on the accuracy of FT or LMA estimates. However, increased level of skill of the interpreter (ultrasonic image evaluator) did improve the accuracy of LMA estimates.

Industry application of ultrasound technology for carcass grading or valuation has been impeded by several problems. Traditionally, ultrasonic images have been interpreted visually by trained evaluators. This required a certain amount of time for analysis of the ultrasonic image. Sophisticated computer programs are available for determining muscle area, but are incapable of automatically discerning between the muscle of interest (most often the longissimus) and other muscles in the image. Therefore, tissue parameters must be identified manually. This may be acceptable for ultrasonic measurement of breeding stock, for which time of analysis is not a factor, but in an on-line industrial application carcass composition must be determined immediately. Liu and Stouffer (1995) reported development of an automated pork evaluation system that eliminates human judgement from ultrasonic interpretation. An average fat and muscle tissue depth is calculated from a single longitudinal ultrasonic scan obtained parallel with the longissimus dorsi. The automatically derived tissue depths provided more precise factors for estimating carcass lean than manual measurements of fat depth, muscle depth and loin muscle area. Another problem facing ultrasonic measurement of carcasses is that hide removal of beef and pelt removal of lamb introduces error for obtaining accurate fat depth measurement. Removal of the hide or pelt introduces small air pockets in the subcutaneous fat layer which may hinder ultrasonic penetration and introduce "noise" into the ultrasonic image. The problem is even greater after carcasses are chilled making it virtually impossible to obtain a clear ultrasonic image. Furthermore, areas of subcutaneous fat may be removed with the hide or pelt from the site of measurement. Cross and Belk (1994) suggested alleviation of problems associated with hide removal by scanning beef or lamb immediately after exsanguination before the hide or pelt is removed.

The biggest problem facing ultrasonic technology is the accuracy of the system. Advances in ultrasonic technology cannot compensate for the many sources and levels of error inherently built into the system. Manual measurement of longissimus muscle area and fat depths on chilled carcasses are often only moderate predictors of carcass composition in any species. This prediction error is confounded when LMA and FT are estimated by ultrasonic imagery; this is not a "perfect" image so we obtain an estimate of an estimator. Further complications arise as the ultrasonic image is interpreted (manually or by computer); now we have an interpretation of an estimate of an estimator. Despite the many sources of error, ultrasonic evaluation is the best technology available for assessment of carcass traits or composition of live animals. As with the optical probes, if additional tissue depths can be obtained, the accuracy of prediction equations will increase.

Bioelectrical Impedance

Bioelectrical impedance analysis (BIA) is a relative new technology in comparison to the reflectance probe or ultrasonography as a means of predicting meat-animal live or carcass composition. The BIA methodology has been used successfully for measurement of human body composition (for a review see Heitmann, 1994) for a number of years. Bioelectrical impedance analysis measures the differences in the electrical properties of the body's *fat mass* and *fat-free mass.* Lean tissue is highly conductive as the bulk of its mass is electrolyte-containing water. Fat is essentially anhydrous and serves as an insulator, exhibiting an impedance to the flow of an applied electrical current. Generally speaking, the combination of fat and fat-free mass comprises the biological system, therefore, it can be assumed that the body's electrical impedance is indicative of the low impedance lean portion (Heitmann, 1994).

Lukaski et al. (1985) described the biological organism as a complex mixture of resistors and capacitors where impedance is a function of resistance (RS) and reactance (XC). The intra- and extracellular fluids of muscle tissue behave as electrical conductors and cell membranes act as electrical condensers. Therefore, RS represents conductance of an alternating current and XC represents the current capacitance. Most BIA studies use the four terminal impedance plethysmograph (Model BIA-101; RJL Systems, Detroit, MI). Four needle electrodes are inserted in series into the live lamb or carcass at anatomically specific locations; one pair near the cranial end and the other near the caudal end. A constant alternating current is transmitted between the outermost electrodes. The electrical impedance (RS, XC) to this current is measured by the innermost detector electrodes.

Bioelectrical impedance analysis has been tested under controlled conditions on all three meat animal species as an estimate of both live animal and/or carcass composition: swine (Swantek et al., 1992), sheep (Berg and Marchello, 1994; Cosgrove et al., 1988; Jenkins et al., 1988) and beef (Marchello and Slanger, 1994). Controlled tests have also been conducted for prediction of primal cut composition of pork Boston butts (Marchello and Slanger, 1992), beef cow primal cuts (Slanger and Marchello, 1994), breeder turkey hens (Grimes et al., 1990) and broiler chickens (Renden et al., 1988).

Lukaski et al. (1985) divided a biological organism (in their case the human body) into a fat and a fat-free mass. Studies using BIA have reported different definitions for the fat-free component as the dependent variable in the BIA equations. The components of interest have been:

1. *Fat-free mass* (Berg and Marchello, 1994; Swantek et al., 1992; Grimes et al., 1990), defined as: BW - (BW × %fat);
2. *Fat-free soft tissue* (Berg and Marchello, 1994; Jenkins et al., 1988), defined as (%protein × BW) - (%moisture × BW);
3. *%Protein* (Renden et al., 1988), chemical analysis of protein;
4. *Fat-free muscle* (Marchello and Slanger, 1992 and 1994; Slanger and Marchello, 1994), defined as chemical analysis of fat and protein of dissected muscle;
5. *Weight or %dissected carcass lean* (Marchello and Slanger, 1992), defined as dissected lean tissue/BW; and
6. *Weight or % of boneless closely trimmed primal (or) retail cuts* (Slanger et al., 1994).

Slanger et al. (1994) are the only research group to have tested the applicability of BIA in a commercial lamb packing facility. They reported that BIA measurements obtained on market lambs and/or their carcasses had great potential for the prediction of kilograms of retail-ready product. They concluded that bioelectrical impedance can separate animals and/or carcasses of the same weight according to leanness and leaner animals and/or carcasses of the same weight have less bone and trimmed fat. Swatland et al. (1994) stated that replacement of hand-held probes by robots is in progress and could change meat distribution and marketing. Slanger et al. (1994) agreed and contended that BIA is a practical methodology that has the capacity to be obtained in an on-line industrial setting by robotic control.

Bioelectrical impedance analysis is appealing as it has applications for predicting composition of the live animal or carcasses. It is simple, affordable, nondestructive and portable. When combined with live, carcass or primal cut weight, BIA has proven to be a very accurate predictor of lean, fat-free lean or weight of boneless, retail-ready cuts. A disadvantage of BIA is that it is an "all or none" methodology that predicts the "fat-free" component only. The homogenous application of an applied electrical current throughout the animal (carcass) allows for determination of total lean but not for lean distribution within the animal (carcass).

Electromagnetic Scanning

The conductivity difference between fat and lean tissue is also used in electromagnetic scanning for the measurement of total body electrical conductivity (TOBEC). The technology uses a low-level magnetic field generated by a copper coil wound around a Plexiglas tube. A carcass can be passed through the field on a conveyer belt. Any muscle (the conductive portion of the carcass) present in the field will temporarily absorb energy while fat and bone absorb little energy. Since a carcass is moving through the field, the energy absorption can be plotted as an electromagnetic absorption curve which gives an indication of the amount of lean in the field at any given position. This allows quantification of lean in the various parts of the carcass (primal cut composition) as well as the total lean mass. While the methodologies are similar, TOBEC should not be confused with bioelectrical impedance. Bioelectric impedance involves direct application of an electrical current for direct measurement of the systems impedance, where as TOBEC technology is a completely noninvasive method based on the physical principle of electromagnetic conduction.

Electromagnetic (EM) scanning has industry appeal as a means for establishing whole carcass value-based pricing because it has the capacity to distinguish primal cut composition. Boland et al. (1995a) reported that the determination of pork carcass primal cut lean would allow the packer the capacity for development of a price discovery system measuring total carcass value. EM scanning is currently the only technology functioning in an on-line industrial setting which collectively measures the cumulative amount of lean within a carcass from end to end (Berg et al., 1994a). Accurate estimates of primal cut composition have been reported for on-line prediction of ham, loin and shoulder lean from EM scans of hot pork carcasses. Berg et al. (1994b) found 98 and 95% of the variability in dissected lamb carcass and leg lean, respectively, were accounted for by hot carcass weight and EM scan variables. A larger study by Berg et al. (1997) reported prediction equations for EM estimation of dissected lean tissue from the lamb leg, loin, rack and shoulder. The most accurate equations were generated for the prediction of total carcass lean (R^2 = 0.88; RMSE = 0.73 kg) and leg lean (R^2 = 0.84; RMSE = 0.36 kg). The amount of muscle in the loin (average = 1.2 kg) and rib (average = 1.0 kg) is likely too small for more accurate detection from EM scanning.

A disadvantage of EM scanning technology is equipment price. Initial equipment costs are high and considerable renovation must often occur to accommodate on-line implementation of the carcass scanner. Another liability of industrial application is the necessity to remove the carcasses from the rail for scanning. The industrial installation reported in Berg et al. (1994a) operates at a line speed of 340 pork carcasses per hour. At this speed, plant personnel have time to re-gambrel carcasses as they exit the EM scanner. However, facilities operating at more rapid line speeds may be unable or unwilling to manually re-hang carcasses. Tests conducted in a pork slaughter plant in the Netherlands have addressed this issue by engineering an on-line system comprised of a nonconductive rail running through the EM scanning chamber. The carcasses are transported through the chamber without the need for removal from the line or manual re-hanging.

Future of Carcass Assessment Technology

Tremendous potential for market expansion exists for all meat species. Whether the expansion is in the domestic or export markets, it will only be achieved by those species that improve the consistency and quality of their products in line with consumer desires. Consistency and quality can be achieved by continual assessment coupled with prudent use of the information in a feed-forward and feed-back information system.

Technological developments in the biomedical and aerospace engineering fields provide a tremendous base of sensor technology that has the potential for assessing nearly any carcass trait that is of economic importance. The adaptation of this technology to the meat industry will not happen automatically. Each meat species will have to support the research and development required to meet their specific requirements. Development takes time and the longer the delay in development the more likely a specie will loose markets to other species or to other countries that go ahead with the development.

Conclusions

Development of a lamb procurement system based on a carcass merit or compositional basis could help the U.S. sheep industry increase competitiveness in the marketplace with other animal protein products and suppliers of foreign lamb. Logically, to procure lambs on a carcass merit system, methods to determine carcass composition or cutability have to be developed. These methodologies should be accurate and precise, be practical for an industrial setting and have the confidence of the lamb producers and buyers. There has been much laboratory research conducted on determining carcass, primal and retail cut composition and cutability. There is a real need to research these methods of determining carcass composition in an industrial setting. Systems of price discovery and evaluation of equations to prevent inadvertent bias also need to be fully investigated before a carcass component pricing system can be implemented. The type of technology used in a component pricing system will be dependent upon industry commitment to the process, the level of accuracy and precision desired by the industry and the type of information that will be needed in price discovery models.

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Demand and Consumer Issues

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Introduction

Demand is not a concept with which most livestock producers, trade associations and those who observe and write about livestock and meat markets are comfortable. Yet, it is the demand side of the price equation that determines the long-term economic viability of any marketable commodity. The livestock markets in general, and the lamb market in particular, are no exception.

The first step, therefore, in looking at consumer reactions to lamb offerings is to establish a context within which demand can and should be considered. There are a few basic principles that need to be established. In no particular order of importance, these basics include: 1) the law of demand; 2) the economic factors that determine the level of demand at any particular point in time and which can become important demand shifters; and 3) the important distinction between the level of demand and quantity demanded. In this article, these basics will be discussed and used as a foundation upon which to build more effective understanding of what is happening to demand for lamb and why and what those developments mean for the future.

Key words: lamb, value, demand, consumers, change, prices.

The Law of Demand

The "law" of demand dictates that at any particular point in time with consumers' preference patterns, incomes and the prices of other products constant, more of any product will be taken only at a lower price. This basic principle is the reason that price specials are used to move increased quantities of product into consumption. More pork chops, beef briskets, chicken breasts or lamb chops will be taken by the typical meat consumer only at a lower price. Demand is a schedule of the quantities that will be taken at alternative prices, and at any one point in time, that schedule is fixed. For an individual consumer example for lamb chops, see Table 1.

This hypothetical and rational consumer will pick up a second package of chops – perhaps to freeze and use at a later date – only when price has declined from \$6.79 to \$4.99 per pound. Other lamb consumers would respond quicker, or slower, as prices decline and new or occasional lamb customers will start to buy lamb more frequently at the lower prices. At any point in time, the aggregate price/quantity schedule across all consumers would tend to look like the graph in Figure 1. The aggregation across consumers "smoothes" the reactions of individual consumers and generates this typical shaped demand curve.

The shape of the curve suggests, intentionally, that the response of current and new lamb customers to lower prices is not at a fixed rate. At lower prices, a \$0.50 per-pound price reduction might attract more new customers than would a \$0.50 reduction at higher prices. This implied relationship between changes in quantity taken in response to changes in price is technically defined as:

$$\frac{\text{Percent Change in Quantity}}{\text{Percent Change in Price}}$$

This is referred to in the economics literature as the own-price elasticity of demand (elasticity).

In the fresh meat market, store managers will understand and use this concept. A product with an elasticity measure of -1.5 would be a much better candidate for an advertised price special than would a product with an elasticity measure of -0.5. The negative sign indicates that quantity and price move in opposite directions in moving along a demand curve, but the quantitative response to a 10% price discount will be significantly different in the two cases. A 10% price discount on a product with elasticity of -1.5 prompts a 15% increase in quantity taken and brings shoppers into the store. A 10% price discount, if elasticity is -0.5, brings only a 5% increase in quantity taken and is much less effective in bringing customers into the store.

The law of demand thus ensures that the demand for lamb products will slope down and to the right. Any seasonal or other increase in quantity

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offered to the marketplace will tend to clear through the marketing channels only at lower final user prices if the demand schedule stays the same. Analysis of the demand for lamb is limited by the absence of publicly available retail prices, but most analysts indicate the elasticity coefficient for lamb is in the -0.50 to -0.65 range, suggesting even small increases (decreases) in quantity will prompt relatively large decreases (increases) in price (Purcell, 1989; Texas Agricultural Market Research Center [TAMRC] Lamb Study Team, 1991).

This law of demand and the related inelastic (elasticity coefficient less than 1.0 in absolute value) nature of demand for lamb is the source of the obvious inverse relationship between production and lamb prices that is evident in Figure 2. Since 1970, year-to-year changes in lamb prices have been closely tied to year-to-year changes in production. In 1996, lamb production dipped to the 270 million-pound area, roughly 50% of the production level just below 550 million pounds in 1970. The lamb prices shown in the graph have been adjusted to remove the influence of overall inflation and the prices have trended lower since the late 1970s. The sharp reductions in production since 1991 have brought short-run increases in price, especially since 1994. Nonetheless, the inverse relationship between quantity (or production) and price is clearly present. If the plot used total disappearance to account for imports, which have moved up toward 25% of the total in recent years, the inverse relationship between this expanded measure of supply and price will still be apparent. It is domestic U.S. production with its highly variable slaughter levels, not exports, that bring much of the variation in supply over time.

In the context of thinking about what influences within-year price levels and even year-to-year price changes, therefore, it appears the first and most important factor is changes in quantity offered to the marketplace. This is typically the case and in a modeling and theoretical context, this relationship can be expressed as:

$$P = f(Q, , ,)$$

Other price-changing factors can be added to the right hand side of this algebraic expression to build a model to explain or predict price, but "quantity" – either domestic production or total disappearance – should go there first.

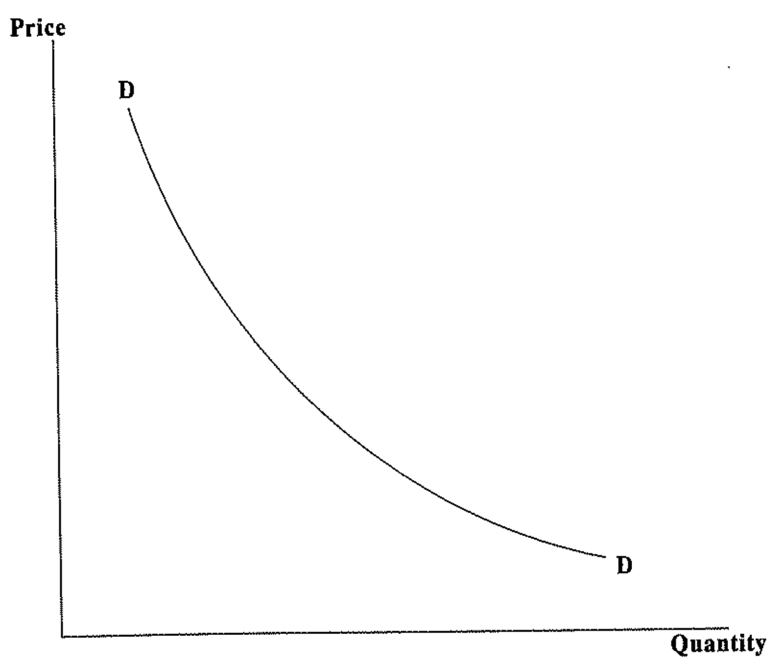
The basic economics at work can be shown graphically as in Figure 3. Two supply functions are superimposed over the demand schedule shown in Figure 1. The S_L and S_H functions are for "low" and "high" levels of supply respectively. Both are shown as vertical lines, not a major abstraction from reality since production and quantity supplied for any particular month, quarter or even year are largely fixed by prior producer decisions on number of ewes in the breeding flock and by lamb feeders' decisions on how many lambs to place on feed. The graphics in Figure 3 look "academic" on first glance, but they are important.

Any movement of supply along a fixed or constant (non-shifting) demand function will guarantee a move in price in the opposite direction. The elasticity of demand along the segment of the demand curve will dictate how large the price change will be for a given change in (a shift in) supply. Both domestic production and imports go into making up the total supply, of course.

Table 1. A hypothetical consumer demand schedule for lamb chops.

Price, $/pound	Quantity, number or packages
$6.79	1
$6.29	1
$5.49	1
$4.99	2
$4.59	2

Figure 1. A typical shape for consumers' demand schedule for a meat product.



One obvious way to increase lamb prices, then, is to decrease supply. Figure 2 shows that production is decreasing in recent years. So is total supply, even with more imports. Inventory numbers were near 33 million head in 1960, trended down to the 10-to-12 million area in the 1980s and dropped again to the 8-million head area on January 1, 1997. It is clearly supply-side reductions that are bringing the higher prices of recent years and the industry is paying a severe price in terms of downsizing and forced disinvestment as producers leave the industry. Annual average lamb prices at San Angelo, TX, nominal prices before adjusting for inflation, averaged in the $50s as recently as 1990 and 1991. Prices moved above $70 (and into profitable territory for most producers) only in 1995 through 1997 as the reduced supplies were taken by consumers at higher prices. This price/quantity pattern is very consistent with the law of demand. Increased quantities will be taken only at lower prices, but higher prices will be paid for reduced quantities.

Let's illustrate further. In 1991, commercial production in the U.S. was near 360 million pounds. In 1996, it was near 278 million and imports had grown some compared to 1992. For illustrative purposes, then, let's use 360 million to represent S_H in Figure 3 and use 290 for 1996 to represent S_L in Figure 3. At the live animal level, demand is always more inelastic than at retail. If we use -0.6 as a farm-level elasticity then the 22% reduction in supply should bring a 37% increase in price if demand is constant. If the inflation-adjusted price for lambs was around $40 in 1991 (see Figure 2), then price in 1996 should be 1.37 × $40.00 or around $55 if the only thing that had happened is the decrease in supply. In other words, P_L in Figure 3 would change from $40 to $55, the price at P_H. Reference to Figure 2 suggests the inflation-adjusted price *was* near $55 in 1996, about in line with what we would expect if demand is constant and the only change is in quantity supplied to the market. *It is the reduction in supply coming from a downsizing industry that has brought the high lamb prices of 1997.*

Determinant of Level and Shifts in Demand

Supply changes are thus very important explanatory factors in short-run changes in lamb prices. Within-year, and even year-to-year, supply changes will usually be the most important factor in explaining changes in lamb prices. But accepting that truism brings important insight. Higher lamb prices that are the result of significant decreases in supply available to the marketplace are not necessarily good for the industry. Very importantly, *those higher prices are not and should not be seen as indications that demand for lamb is increasing*. Because of the

Figure 2. Inflation-adjusted San Angelo, TX, slaughter lamb prices (CPI, 84 - 82 = 100) and U.S. commercial production (1970through 1996).

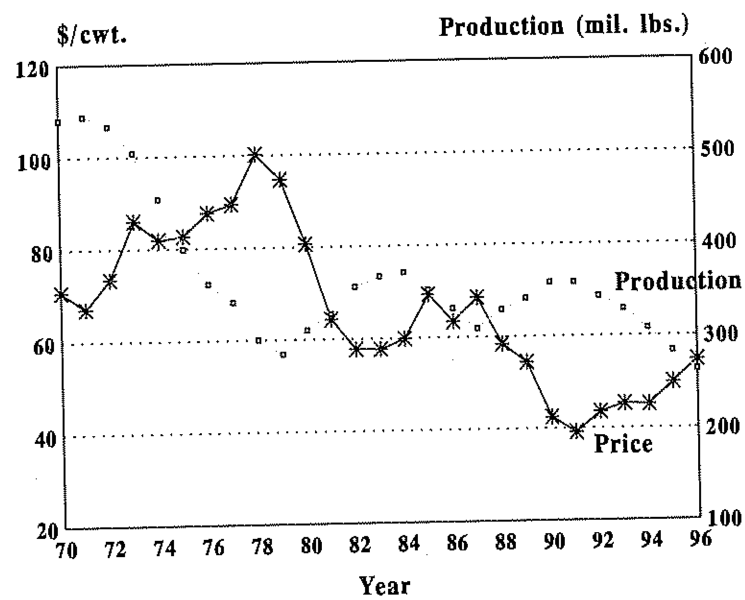
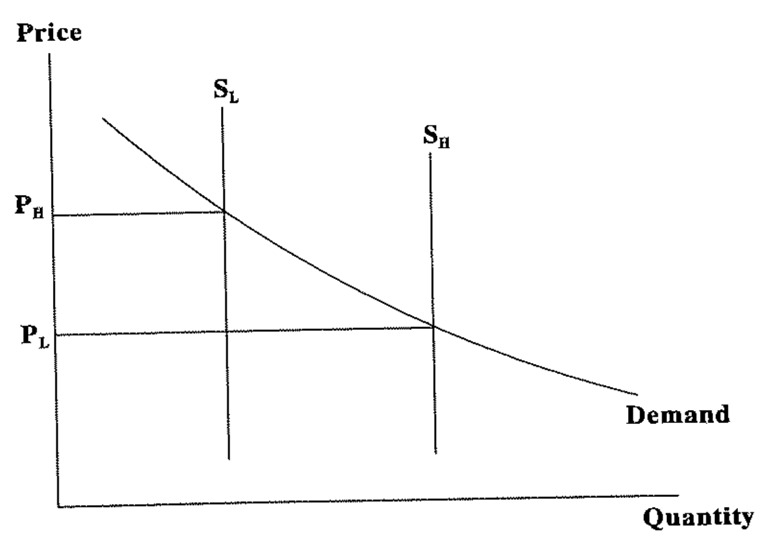


Figure 3. Basic supply-demand relationships for lamb.



law of demand, supply decreases will bring increases in price if the demand level or strength is constant. Supply decreases *can bring increases in price, if the supply decreases are of sufficient magnitude, even when demand is decreasing*. Over time, however, the strength of consumer demand and developments in demand will be the important determinant of the direction of price movement, producer profitability and industry viability.

When the period of consideration gets longer than a month, and especially when it is a year or longer, other price moving factors have to be added as potential explanatory factors:

$$P = f(Q, D_S)$$

Where:

D_S = the strength or level of demand; and

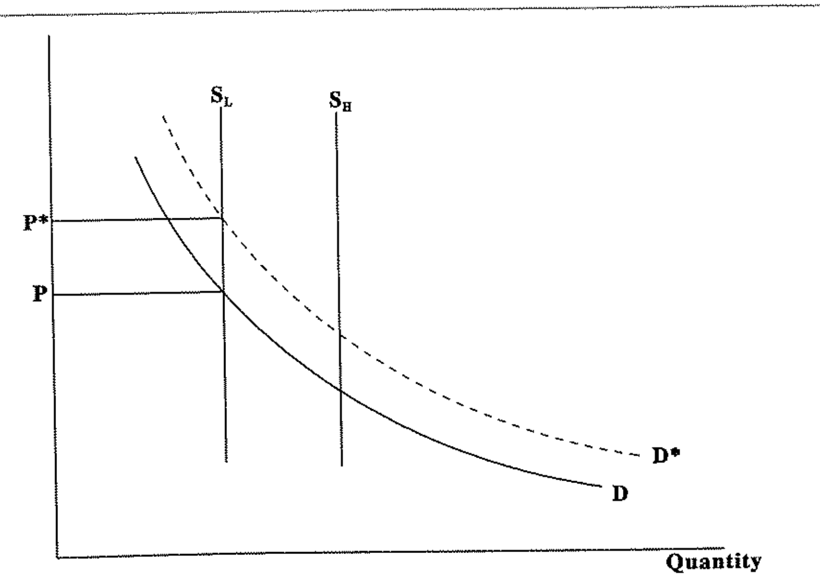
Q = supply

It is no longer just supply, represented by Q, that is a major price mover.

A consumer's demand schedule is defined for constant tastes and preferences, constant income levels and constant prices of other products. These are the *ceteris paribus* conditions in the economic literature, referring to "things held constant." When and if these factors change over time, the *level* of demand changes and the entire schedule or curve shifts.

Economists define the concept of income elasticity to help analyze the direction in which demand will shift when consumers' incomes change. It measures the change in quantity taken at constant prices in response to changes in consumers' incomes. Generally, the income elasticity for meats is positive and significantly different from zero. Consumers' incomes, after adjusting for overall price inflation, are trending up in the U.S. This would tend to shift the demand for lamb to D^* in Figure 4 and would offset, or help offset, the price discovery forces of a move in supply to S_H. Conversely, if supply is decreasing from S_H to S_L, and it *is* currently decreasing in the industry, then lamb prices would be boosted even further by the demand-increasing influence of rising incomes. Prices would be at P^*, up from P, when demand and supply balance and the quantity offered by producers is the same as the quantity desired by consumers at the higher income levels. Demand has increased, meaning a willingness to pay higher prices for the same quantity or a willingness to take more quantity at the same price. *It will be the ability of the industry to stimulate and increase demand that will determine whether the long-term decrease in numbers and market share can be halted and reversed.*

Figure 4. Demand-boosting influences of increases in consumers' incomes.



The income elasticity for lamb is hard to measure given the sparse data on lamb consumption. For the other meats it is often near 0.1 or 0.2, suggesting the demand-shifting influences of rising consumer incomes is quite small. A measure of 0.1 would suggest a 10% increase in consumers' incomes – a large income increase – would increase the quantity taken at constant prices by only 1.0%. Realistically, then, the industry cannot wait for improving consumer incomes to boost demand for lamb.

Prices of other products may be more important than consumers' incomes in setting the level of demand for lamb. There is a cross elasticity concept to capture this "crossover" effect. Since the late 1970s, the inflation-adjusted prices for beef and pork have been trending lower. Inflation-adjusted prices for poultry trended lower and then "flattened" in recent years. Decreasing prices for potential substitutes would tend to decrease demand for lamb, moving it down and to the left. Whether this would have more than offset the price-boosting influence of consumers' incomes is an empirical research question, but most analysts would suggest changes in prices of substitutes will be a more important demand shifter than changes in consumers' incomes. The important point is that decreasing prices for substitute meats will tend to decrease the demand for lamb and the demand surface for lamb has apparently been decreasing over time.

Tastes and preferences is the remaining "demand shifter," and this is arguably the important one where lamb is concerned. A multitude of surveys at the retail level plus "quality audit" studies done for both beef and pork have brought wide agreement on what consumers want in a meat product (Purcell, 1989; National Beef Quality Audit, 1995, Ward et al.).

They want:

1. High quality;
2. Consistent high quality; and
3. Convenience in preparation.

The modern meat consumer is typically in a family setting with more than one wage earner, is interested to varying degrees in trying to control consumption of fat and is following a mobile "on the go" lifestyle. Time spent preparing meals is down sharply across the past two to three decades and the product offering must change with the times and be tailored to meet the needs of a changing consumer. It is not just price that affects consumers' buying behavior as evidenced by this quote from a study of lamb customers in the Washington, DC, suburbs (Purcell 1993a, p. 20):

"In high-income market areas characterized by families with two professionals working outside the home, price may not be the major point of consideration in a merchandising and advertising effort. Non-price attributes such as quality and other factors that could boost the perceived value of the product (lamb) might be equal to or more important than featuring price in a merchandising program."

Examination of price-quantity data suggests demand for lamb has decreased significantly in recent years. Analyses of available data supports that inference (Purcell, 1989). Figure 5 uses commercial production data and inflation-adjusted lamb prices at San Angelo, TX. This plot replaces a more typical retail price/per-capita consumption plot because retail prices are not available for lamb for recent years and the per-capita consumption (disappearance) data are suspect because of the limited sample from which the data are calculated. To the extent that price spreads between the live lamb level and retail levels have increased over time (and anecdotal evidence suggests they have; Purcell, 1995), any conclusions about decreases in demand will be overstated by using live lamb price data. But a negatively sloping demand curve that passes through or near the coordinates for the 1990s (the numbers in the plot indicate year, with 96 = 1996) is well below and to the left of a curve representing the 1980s. Obviously, the surface for the 1980s is below that for the 1970s. If the imports of recent years were added to production levels to generate total supply numbers, the plot would change very little. The inferences on what is happening to the demand surface over time would still hold.

When examining price/quantity data, economists worry about what brought or prompted the observed pattern in plots like Figure 5 – the "identification" problem. Was it shifts in supply, shifts in demand or both that brought the price pattern? In most cases, the correct answer is likely to be "both," and indeed it appears that way for lamb. If 1986 is compared with 1996, it is clear that in 1996 a lower level of production moved into consumption at a lower price. *This means demand in 1996 is assuredly lower or weaker than in 1986 no matter what prompted the move from 1986 to 1996.*

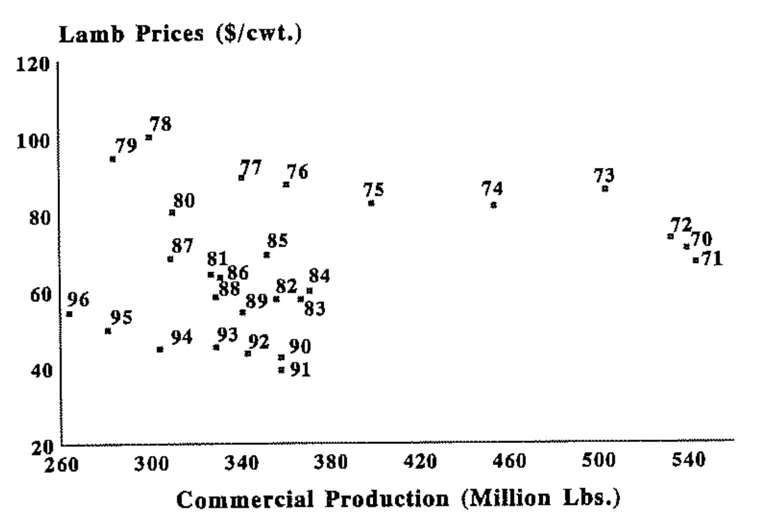
If 1996 is compared with 1991, it is not so clear what is happening. After the decline in the demand surface (visualize a negatively sloped curve) from the mid-1980s to the mid-1990s, a *shift* from one demand curve to a lower one, it appears that supply may be shifting to the left (decreasing) and "tracing out" a roughly common demand surface for the 1990s. What is happening, it appears, is that the disastrously low prices of 1991 and 1992 and the later loss of the wool incentive programs via a policy move is prompting producers to exit the industry. The related reductions in supply and in the size of the industry are bringing the higher prices of recent years. The average price for 1997, on still smaller levels of production, is likely to be above those for 1996.

In the long-term, it is apparent that decreases in demand are bringing the downsizing of the industry and the related losses in market share. If this trend is to be reversed, measures to reverse the negative consumer attitudes toward the product offering must be adopted. This will be examined later in this article. There is another article in this Special Issue that looks ahead for the industry (Purcell, pages 106-120). Before that can be done, it is important to look at the confusion that is prompted by failure of industry leaders, analysts and the media to understand and reflect in their work the differences between a change in demand and a change in quantity demanded.

Demand and Quantity Demanded

Throughout the livestock and meats sector, there is a broad tendency to see quantity as demand. An electronic wire service will quote a producer, trader or market observer who is lamenting the day's lower prices in the presence of "strong demand for the product." If the reference is to beef, it

Figure 5. Commercial lamb/mutton production and deflated lamb prices (CPI, 82 - 84 = 100), Choice, San Angelo, TX (1970 through 1996).



may be a matter of over 200 loads of boxed beef having been sold by noon, an unusually large daily movement. But examination of boxed beef cutout values when they are released at noon shows those values are down almost \$2.00 per hundredweight and down a bit more than 2.0% from the previous day. In what sense, intuitively or scientifically, is this increased movement indicative of strong demand? *You can sell any volume in a particular marketplace at some price!*

Figure 6 clearly demonstrates that the increased volume at the lower price, completely consistent with the law of demand, could be on the same demand curve. The shift in daily supply from S to S* moves through the market channels, but only at a lower price P to P*. Examination of the percentage decrease in price associated with the percentage increase in quantity, and awareness of the demand elasticity coefficient for the particular product, is needed before any conclusions can be drawn about the level of demand. *Demand is price and quantity, not just quantity and not just price.* The ability to effectively distinguish between quantity demanded and demand is worth whatever time it takes to get it done.

To illustrate this important point, assume boxed beef values were \$95.00 per hundredweight before the change. The value or "price" at which the increased volume clears the market is \$93.29, a decline of 1.8%. If the volume of boxes had only increased 1.0% and elasticity of demand at this level in the system is -0.67, an expected price can be calculated if the only thing that has changed is supply and demand is constant:

$$\text{Elasticity} = \frac{\text{\% change in Q}}{\text{\% change in P}}$$

Or:

$$-0.67 = \frac{0.01}{X}$$

Where:

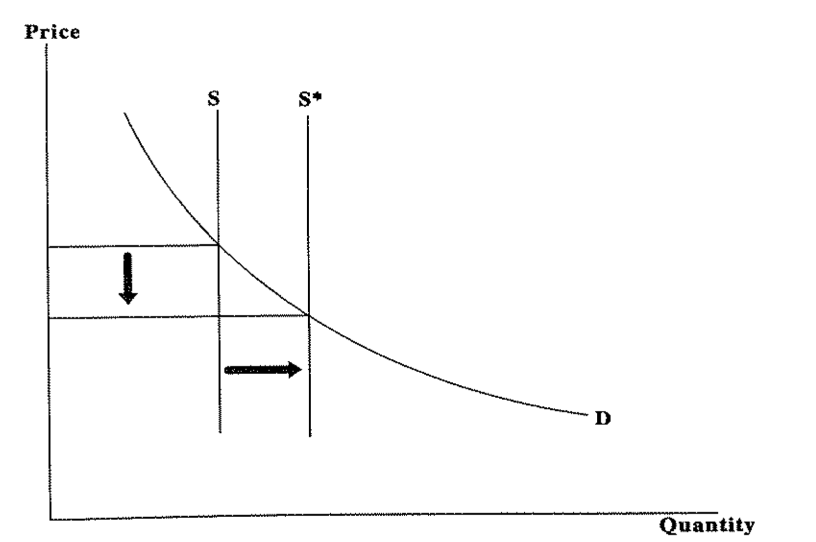
X = expected change in price.

Solving for X:

$$X = -0.015$$

Since price was down 1.8%, not the expected 1.5% (note the -0.015) that would be seen if demand is constant, *there is reason to argue demand has actually decreased. This creates a much different perspective of what is going on in the marketplace on a day-to-day basis as well as over time. It shows clearly that increased volume is not increased demand.* Obviously, viewing what is happening in the marketplace in this way requires knowledge of the elasticity of demand. But the elasticity parameter is estimated in numerous research publications and the ability to handle the elasticity framework to see what is (or is not) happening to the level of demand requires only minimal analytical abilities. But it is very important.

Figure 6. Increased quantity or volume of movement at a lower price.



The other side of the coin is now present in the lamb market. Lamb prices are going up, so many observers conclude demand must be increasing, but that assertion – one that is being voiced in today's lamb markets – can clearly be wrong and it can be very misleading. *Prices are up primarily because the sector is downsizing, losing market share and seeing producers leave the business.* It is a leftward shifting supply function that is bringing the higher prices, not strength in demand. Over time, and under closer examination, demand for lamb appears to still be decreasing. The slope of any demand surface representing any year 1991 through 1996 in Figure 5, given the scales employed on the axes and an elasticity near -0.6, would be steeper than a curve passing through all of the 1991 through 1996 coordinates. This suggests the shorter-run demand surface for 1996 is down and to the left of that in the early 1990s – and demand has decreased again.

Looking Ahead

It is a difficult time for the sheep sector. Earlier analysis confirms that once producers leave the sheep business, it is very difficult for them to return to the business at a later date. The supply response path is not symmetric and leaving the industry in response to lower prices is much easier than getting into (or back into) the business when prices increase (Purcell et al., 1991). This issue will be explored in more detail in the last article of this Special Issue (Purcell, pages 106-120). The long-standing and continuing problems on the demand side are the source of the downward spiraling numbers, production and industry influence. Here, we need to deal with specific issues and needs surrounding the demand side of the price equation.

An earlier "needs assessment" conducted by the American Sheep Industry Association (ASI) suggested there would be difficult times ahead.

Sheep producers were in general agreement that consumer-level demand and acceptance of their product was a high priority issue, but there was another side to this insight: Producers generally believed ASI could fix the consumer-level problems on their behalf with prevailing resources, personnel and expertise. In the mid-1990s, the wide gap between producers' confidence and the ability of industry leadership to forge a consensus and deal effectively with consumer-level problems was becoming very visible. Consumers' attitudes, lifestyles and what they want from meat products have changed dramatically since the 1970s, but changes in the lamb product offerings, especially in fresh lamb, have been minimal. Industry efforts were designed to attract consumers back to the prevailing product offering by generic advertising, but that strategy has failed in virtually every application – from beef to U.S.-built automobiles to IBM's late 1980s efforts in personal computers. In virtually all of these and other examples, the industry or sector involved had to change, or start to change, an outdated product offering before consumers "came back." It was true of the automobile industry (remember the huge cars of the late 1970s?), it was true of IBM where a major change toward "consumer driven" has been made in a refocused PC sector, and the need is still there in beef.

These points need emphasis. Many modern consumers do not have a positive attitude toward the traditional fresh lamb product offering. Many do not know how to prepare a leg – and they will not, of their own volition, bother to learn. Lamb chops look high in fat – and consumers are focusing more attention on percent of calories from fat. There are few lamb offerings that work in the microwave, but the surveys show microwaves in a huge majority of American homes. Often, no thought is given to the evening meal until whoever is to prepare that meal steps on the commuter train to start home. If it is not quick and easy to prepare, it is not in the list of possibilities for most of those meals. These trends are all counter to acceptability of the largely outdated fresh lamb product offering and the consumer trends will not reverse themselves. *The industry will not be able to drag a reluctant consumer back to the old offerings. It will have to change the product offerings.*

The negative vote on the check-off referendum raises the importance of effective demand-side programs and makes the changing of the product offering still more difficult. Producers and processors will have to find ways to work together, share the risks and form alliances with a goal of modernizing fresh lamb offerings. If that is not or cannot be done, then the domestic industry will shrink still further under the pressure of further declines in demand and the market vacuum will probably be filled by other producing countries as we see imports grow. *The path back to competitiveness and profitability in the sheep business must be built on at least one stepping stone that does something about the lingering demand-side problems for lamb.* The prescription for the future offered in the last article in this Special Issue (Purcell, pages 106-120) will come back to and deal with this issue and the related needs.

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United States Imports and Exports of Sheep and Lamb: Current Situation and Trends

Steve Meyer[1] and David P. Anderson[2,3]

Summary

Lamb and mutton imports have been of great concern to U.S. producers for a number of years. In recent years as domestic (U.S.) production has declined, imports have increased. The impact of increasing imports on domestic lamb prices and producer returns has been the source of a number of trade disputes since the mid-1980s. The results of what little research done on the impact of imports on the domestic market have been mixed, implying that imports have very little impact on the domestic market. However, recent trends might alter these results.

The U.S. exports very little lamb and mutton. Live sheep, particularly mature cull sheep, have been exported in large numbers in recent years, primarily to Mexico. The Mexican economic crisis of December 1994 and early 1995 slowed sheep exports dramatically.

The future probably holds increased levels of lamb and mutton imports. Many market participants expect retailers to continue to look to foreign suppliers as the domestic supply of lamb continues to shrink. Imports will become much more directly competitive with domestic product.

Key words: exports, imports, lamb, mutton, trade.

United States Imports and Exports of Sheep and Lamb

Current Situation and Trends

The most recent sharp decline in sheep numbers this decade, brought on by low lamb prices and the loss of the wool program, continued the long-term downward trend in sheep numbers since their peak in 1942. Many previous reports document this decline in the U.S. sheep industry. Therefore, no in-depth discussion of the decline appears in this article.

As sheep producers struggled to survive tough economic times during the 1990s, concern regarding the impact of lamb imports and international trade, in general, on the domestic market increased. While domestic lamb production declined during the 1990s, imports increased both in absolute terms and as a percent of production. There has been a great deal of disagreement about the magnitude of impact that imports have had on the domestic industry. These disagreements have led to a number of trade confrontations over the past several years.

It's important to note at the outset that trade is viewed as being beneficial by most people. That is not to say that everyone benefits from trade. Clearly, some do not. In a nutshell, trade is beneficial because it enables a country to produce a good that it is most efficient in producing and exchange those for goods that it produces less efficiently. In that way, goods can be purchased for their lowest cost and resources managed more efficiently, benefiting both partners in trade. Obviously, trade is a two-way street. It is difficult to extract the benefits of trade without assuming some of the costs. Today's sheep industry faces both sides of the trade issue. Producers are threatened by lower-cost imported lamb while consumers can benefit from the lower priced imports.

This article summarizes recent events in lamb trade disputes, discusses trends and the current situation in lamb and mutton imports and reviews economic literature on the impact of lamb imports on the domestic market. A brief discussion of live sheep and lamb trade also appears. The article

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concludes with some expectations of future trade in lamb and mutton.

Imports

An understanding of how individual participants in the marketing chain view imports is essential to understand the controversy and arguments surrounding imports. The discussion about imports will focus primarily on lamb and mutton meat. Live animal trade is limited, making up less than 1% of production on average (Steller, 1991). In the last 20 years, complaints about live imports occurred only in 1989 when U.S. feeding interests imported around 100,000 head of feeder lambs from New Zealand (American Sheep Industry, Inc. [ASI], 1990). At the time, prices reacted negatively as the market feared the effects of the increased supplies. Many of the U.S. producers considered filing a countervailing duty petition. U.S. prices fell to the point where importing was no longer profitable before producers could file the petition.

According to various consumer studies commissioned by the ASI (GMA Research Corporation [GMA], 1988 to 1996), the majority of consumers traditionally viewed imported lamb as a lower-quality product, yet a substitute for domestic lamb. Many of these studies in the past showed that many consumers thought that Australian and New Zealand products were more consistent in quality than domestic lamb. However, the introduction of quality and yield grading in the U.S. alleviated some of this advantage for imported lamb. In recent years, these studies indicated that consumers have been less likely to differentiate between imported and domestic products in quality. The lack of availability and near-record high prices for domestic lamb in recent years may have contributed to less choosy consumers. At the same time, improved technology in freezing product may have muted any advantage the domestic industry had in supplying fresh product compared to the imported frozen product.

Retailers and/or wholesalers traditionally viewed imported meat as an alternative to domestic supply. Attitudes about quality depended a great deal on the customer that the retailer/wholesaler served. Customers who demanded larger portion sizes often received American lamb while customers desiring smaller portion sizes often received imported lamb. Similarly, customers insisting on fresh product typically received American lamb. Recently, lamb meat wholesalers and retailers have begun to consider domestic and imported product comparable in terms of quality, palatability, fat content, consistency of product specifications, shelf life, availability, packaging and servicing (U.S. International Trade Commission [ITC] Pub. 2915, 1995).

Domestic packer/breakers have recently begun to change their attitudes concerning imports. A few years ago they would have viewed imports strictly as competition. Now, packers are starting to take the view that the imported product might serve as an alternative source of raw product that they can use to meet their customer's needs. In 1996, one packer asked for and was granted permission to bring fresh and chilled lamb carcasses into the U.S. from Australia and have them USDA quality and yield graded. Under the provisions of the agreement, the USDA requires that carcasses be presented as if slaughtered on the premises. The carcass would then receive the quality and yield grade rolls along with a third roll that would identify the country of origin of that carcass (Meyer, 1996). As of this writing, at least one more major packer expressed interest to the authors in supplementing domestic product with imported carcasses.

The U.S. producer views imports as perfect or near perfect substitutes for domestic lamb. Under this view, any change in imports would cause prices to react the same as a corresponding change in domestic production. In the domestic producers mind, imports drive prices down to the same degree that an increase in domestic production would drive prices down (New Zealand Meat Producers Board, 1995).

Exporting countries, and the U.S. companies that import the lamb, view their product as a non-substitute for domestic lamb. In their view, the imported product comes into the U.S. primarily frozen whereas the domestic product is primarily fresh and chilled. At the same time, the cuts are a different size. Australia and New Zealand traditionally focused on wool breeds while the U.S. focused on meat and/or dual purpose breeds. This difference in goals led to differences in animals. Domestic carcasses over the past several years averaged around 60 to 66 pounds while Australian carcasses averaged around 40 pounds and New Zealand carcasses averaged around 30 to 35 pounds (Steller, 1991; U.S. ITC Pub. 2915, 1995; U.S. ITC Pub. 2900, 1995). Besides the physical differences, most imported product goes into the hotel, restaurant and institution (HRI) trade. The majority of the domestic product goes into the retail trade (New Zealand Meat Producers Board, 1995). Given these physical and marketing channel differences, the importing companies and exporting countries often claim there is no impact on pricing of domestic product due to increased imports.

However, around 25% of American lamb does go through the hotel, restaurant and industry (HRI) trade (GMA, 1988 to 1996). In terms of volume, this would be greater than or equivalent to the total volume of imported product brought into the United States. This would indicate that the marketing channel differences are less pronounced than the exporting countries and importing companies would claim.

Obviously there is a great deal of disagreement about the role of imports and how imports effect the market. The perceived effects seem to depend a great deal upon where in the market chain the view comes from. With this in mind, it is interesting to take a look at what has happened with international trade with respect to the U.S. sheep industry over the last two decades.

United States Trade Restrictions

Before looking at recent history, it is worth taking a look at current trade restrictions. Trade restrictions within ovine markets are varied and often confusing. Provisions for live sheep in the Harmonized Tariff Schedule apply to all animals regardless of age, sex or size. Lamb meat imports are subject to only a couple of tariffs that, for the most part, are not more than $0.01 per kilogram. These tariffs will decrease over the next few years under the General Agreement on Tariffs and Trade (GATT) to $0.007 per kilogram (U.S. ITC Pub. 2900, 1995).

Mutton tariff rates vary greatly and differ from lamb tariff rates. In the past, mutton was subject to the red meat import quotas whereas lamb was not (Steller, 1991).

All imports are subject to the health and sanitary regulations administered by USDA. Imports of live animals and fresh, chilled, or frozen meats can only come from countries that the U.S. Secretary of Agriculture has declared free from rinderpest and foot-and-mouth diseases (Sec. 306 of the Tariff Act of 1930).

The USDA administers Section 20 of the Federal Meat Inspection Act (21 U.S.C. 620), which provides in subsection "a" that meat and meat products prepared or produced in foreign countries may not be imported into the United States "... unless they comply with all inspection, building construction standards and all provisions of this chapter (Ch. 12, Meat Inspection) and regulations issued thereunder applicable to such articles in commerce in the United States." (Steller, 1991; U.S. ITC Pub. 2915, 1995; U.S. ITC Pub. 2900, 1995).

Recent Lamb-Related International Trade Disputes

Over the last two decades, the domestic sheep and lamb industry has tried, with varying degrees of success, to establish import restrictions on imported lamb. Since 1981, the U.S. sheep industry filed four countervailing duty and/or anti-dumping petitions with either the Department of Commerce (DOC) or the U.S. ITC.

The National Wool Growers and the National Lamb Feeders Associations filed the first of these countervailing duty petitions against New Zealand in 1981 in the DOC. The DOC ruled that: 1) imports were increasing in quantity and market share; 2) price underselling was taking place; 3) lamb consumption was declining; 4) live lamb profitability was declining; and 5) there was a threat of injury to the domestic industry with New Zealand's large capacity to produce sheep and their stated intent to significantly expand sales in the U.S.

The DOC estimated that there was a net subsidy of 6.19% of the f.o.b. value of New Zealand lamb meat exported to the U.S. However, before the countervailing duty could be implemented, the National Wool Growers and Lamb Feeders Associations withdrew their complaint (U.S. ITC Pub. 2900, 1995).

In 1984, the American, the Denver and the Iowa Lamb Companies filed a countervailing duty and anti-dumping petition with the U.S. ITC and the DOC. These three companies alleged that the New Zealand government subsidized exports from New Zealand and sold lamb in the U.S. at less than fair value. The U.S. ITC and the DOC disallowed the petition with the finding that there was no reasonable indication of injury to the domestic industry as a whole and no threat of injury in the future.

The following year (1985), the same petitioners filed another countervailing duty petition against New Zealand with the DOC. This petition alleged that New Zealand producers received benefits that constituted bounties or grants within the meaning of Section 303 of the Tariff Act of 1930. By filing the petition under Section 303 of the Tariff Act, the DOC did not need to make an injury determination if the exporting country was not a signatory to the GATT Subsidies Code. New Zealand was not a "country under the Agreement."

The DOC's final determination was that certain benefits provided to New Zealand producers, processors and/or exporters did constitute bounties or grants as defined within the meaning of the countervailing duty law. The DOC determined these net bounties or grants to be NZ$0.3602/pound (about US$0.18/pound, given the exchange rate at that time). Initial tariffs were set at NZ$0.31/pound, but were quickly reduced to NZ$0.21/pound due to changes in some of the programs constituting a bounty.

New Zealand phased out many of the programs ruled to provide bounties over the next several years. By 1990, the DOC ruled the New Zealand bounties were *de minimis* (virtually non-existent) and suspended the countervailing duty. After being ruled *de minimis* in 1991, 1992 and 1993, the DOC revoked the countervailing duty (Steller, 1991; U.S. ITC Pub. 2915, 1995; U.S. ITC Pub. 2900, 1995).

In 1994, the United States Trade Representative, at the request of the U.S. sheep industry, asked the U.S. ITC to investigate the competitive nature of the Australian, New Zealand and U.S. markets (U.S. ITC Pub. 2915, 1995). The Australian and New Zealand markets were singled out because 98% of all imports into the U.S. come from these two countries. The fact that imports of lamb moved from 6.7% of the domestic availability in 1990 to 11.5% of domestic availability in 1994 concerned the domestic industry at that time.

The U.S. ITC in this investigation did not find any cause to place restrictions on the imports of lamb or mutton into the U.S. They did find that lamb production was less expensive in New Zealand and Australia than in the United States. The U.S. ITC attributed lower production costs to a variety of reasons.

One reason for lower production costs in Australia and New Zealand was the fact that U.S. sheep producers often give supplemental feedings of grains and hay to sheep. Australian and New Zealand producers feed almost exclusively grass with limited hay usage during extremely cold periods. The report estimated grain feeding accounted for 20% of variable expenses in the United States.

With the higher cost of producing lambs, packers in the U.S. pay more than packers in New Zealand or Australia. At the same time, the U.S. packing sector is more highly concentrated than the packing sector in those other countries.

Australia and New Zealand are not without their own disadvantages. The Australian packers were not as efficient as packers located either in the U.S. or New Zealand due to shipping distances, plant configuration and labor problems. The New Zealand packers were suffering from overcapacity and the industry was downsizing during this period.

The U.S. ITC also determined that the price of imports and the domestic product fluctuated a great deal during the time period examined. The U.S. ITC reported that sometimes domestic meat sold at a lower price, sometimes imported meat traded at a lower price.

Domestic Market Impacts of Imports

Research on the impacts of imports on the domestic lamb market is fairly scarce. Most of the research into lamb supply and demand has focused purely on the domestic industry with little or no separation of import impacts (Abt, 1995). Arguments about the price impact of imports depend on the estimated lamb demand elasticity. The more inelastic the demand for lamb the larger the price impact from increased supply, whether from domestic or foreign sources. The substitutability of imported for domestic lamb will influence the impact of imports on the domestic market. Most studies have estimated an inelastic demand for lamb. Although there have been a few elastic estimates reported, most economists would agree that the demand for lamb is own-price inelastic (a 1%-change in the price of a product will change the quantity demanded of the product less than 1%).

The U.S. ITC used a system of four econometric equations to examine the effect the 1985 through 1990 countervailing duty had on the domestic industry (U.S. ITC Pub. 2900, 1995). The estimated own-price elasticity indicated that the quantity of lamb demanded would decrease 7.8% for every 10% increase in price. The own price elasticity of New Zealand lamb suggested that the quantity demanded of New Zealand lamb in the U.S. would decrease 0.9% for every 10% increase in price. However, the measure was statistically insignificant. The Australian own-price elasticities indicated that the quantity of lamb demanded would decrease 11.4% for a 10% increase in price and was statistically significant. The U.S. ITC did not estimate cross-price elasticities (% change in the quantity demanded of a product due to the % change in price of a different product).

The U.S. ITC concluded that the countervailing duty kept domestic lamb prices 0.2% higher, domestic output 0.4% higher, domestic revenues 0.7% higher and the domestic industry employment 0.4% higher than if the duty would not have been introduced. One million dollars was the estimated net benefit to the industry. However, three million dollars was the estimated loss to consumers due to the higher cost of lamb and the decreased availability. Subtracting the one million dollar gain to the producers from the three million dollar loss to the consumers left a net loss of two million dollars to the U.S. economy.

Abt Associates, Inc. (1995), a private economic firm working on behalf of New Zealand in the competitive condition's investigation in 1995, estimated econometric models that examined the role that imported quantities and imported prices had on the domestic market. Abt patterned the models after those developed by the Texas Agricultural Market Research Center's (TAMRC) Lamb Study Team (1991). Per capita consumption of domestic lamb was specified as a function of wholesale price of lamb, domestic per capita consumption of imported lamb and wholesale price of beef. They concluded that per capita consumption of imported lamb did not statistically explain per capita consumption of domestic lamb. The results might suggest that there is little substitutability between domestic and imported lamb.

Abt Associates also determined that relative prices did not explain changes in import shares. They indicated that it could be due to the variability of imported lamb (shipments do not consistently follow the natural fall of the lamb carcass). They also indicated that it might be due to the fact that domestic and imported lamb were qualitatively different.

From their models, Abt Associates concluded that a 10% decrease in imported price would lead to a 1.4 to 3.8% increase in consumption of imported product. They also concluded that a 10% reduction in imported quantities would increase sales of domestic lamb by 0.14%. At that time, they claimed a total elimination of imports would increase sales of domestic lamb only 2%.

The U.S. ITC used a vector autoregression (VAR) model to examine the impact that imports might have on the domestic market (U.S. ITC Pub. 2915, 1995). The researchers specified the VAR model as a system of annual meat slaughtered and consumed, market price for lamb, wool production, wool price, ratio of the Wool Act's support price to the market wool price and imports of lamb. The U.S. ITC ran five different simulations to determine what factors most effect price and consumption of domestic lamb.

The U.S. ITC determined that lamb imports did displace domestic product at a rate somewhere between the perfect competition claimed by domestic producers and the imperfect rate claimed by importers and exporting countries. A 10% increase in imports displaced and estimated 0.5% of domestic product. The most important factors influencing the domestic prices and quantities were the domestic quantities produced and prices. The U.S. ITC estimated that a 10% increase in lamb meat production would cause the price to drop by 14%, wool production to increase by 2.7% and wool price to decline by 29%. From these estimates the U.S. ITC concluded that increased domestic production would reduce imports.

Recent Trends in Imports

Lamb Imports

Annualized imports of lamb meat were somewhat level through the 1970s and 1980s, ranging from 18 million to 34 million pounds with an occasional jump to the 42 million pound mark. Since 1990 – with the downsizing of the Australian, New

Zealand and U.S. sheep industries – imports have increased markedly.

In 1990, lamb imports were at 23 million pounds, the lowest point this decade. Lamb meat imports totaled 46 million pounds in 1996, double the 1990 level. The reasons for increasing imports mentioned in industry circles have been that decreases in U.S. production meant that wholesalers and retailers who wanted to provide lamb to their customers needed to source the product from overseas.

As a percent of U.S. production, imports ranged from 4.8 to 26% over the last 20 years. Imports' market share increased sharply during the 1990s. As domestic production declined, imports increased in absolute and percent of production terms. Imports reached 26% of production in 1996 (Figure 1).

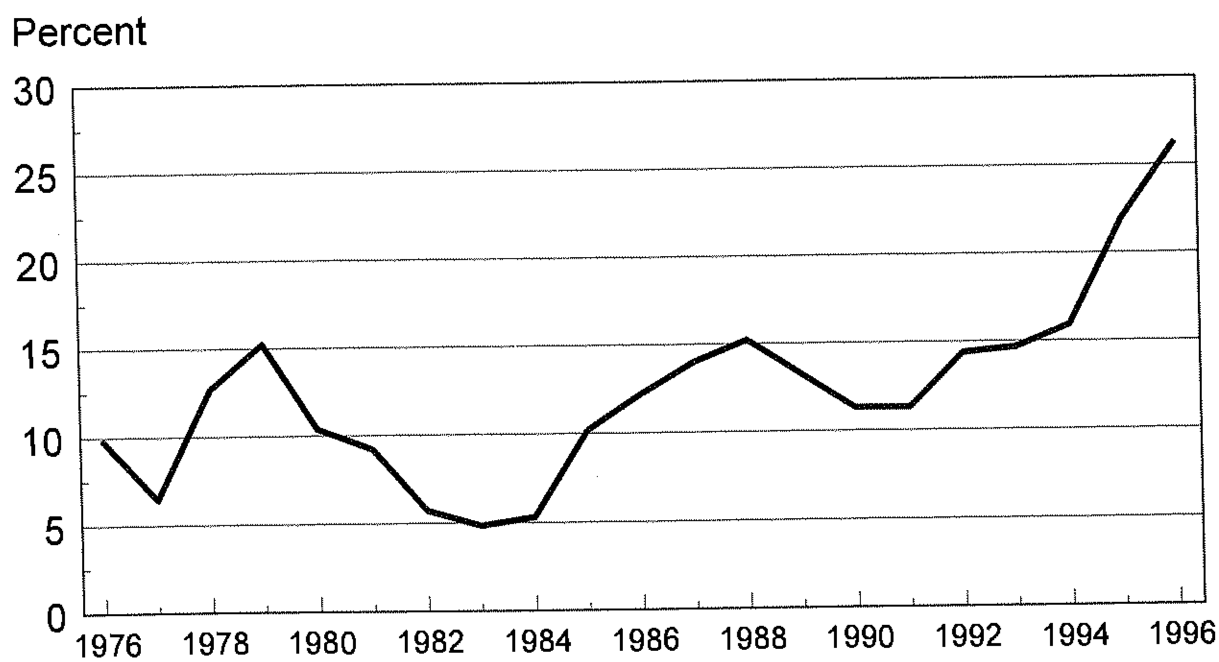
Australia and New Zealand have downsized their flocks over the last several years due to a drought, lower wool values and changing to more profitable enterprises (U.S. ITC Pub. 2915, 1995). With industry downsizing, Australia and New Zealand slaughtered lambs that they normally would have kept for wool production. This increased both countries' meat output. A similar argument is that both countries have increased the use of meat and dual purpose animals and decreased wool producing breeds. However, these arguments are largely conjecture by industry participants and have little empirical evidence to support them other than animal inventory statistics.

Lamb imports come in both carcass and cut form. However, lamb imported into the U.S. in carcass form in 1996 accounted for only 4.6% of lamb imports. The meat can also be fresh and chilled or frozen. Frozen lamb accounts for around 76% of all lamb imports on average (Table 1). This is not surprising given the cost of shipping meat overseas. However, recent domestic industry developments of domestic packers importing or considering importing foreign fresh and chilled carcasses for USDA grading may alter this in the next couple of years.

As stated earlier, U.S. lamb imports come primarily from Australia and New Zealand. In 1996, Australia was the source of 59% of the lamb imports; while New Zealand accounted for 40.5%.

The value of lamb imports has also grown over the last few years. Since 1990, the price per pound of imported fresh and chilled lamb, estimated by dividing the total customs value by the poundage brought in, grew from $1.65 per pound 1990 to $2.64 per pound for fresh and chilled in 1996 (Figure 2). The average price of imported frozen lamb climbed unevenly from $1.19 per pound in 1990 to $1.92 per pound in 1996. The overall average price per pound for lamb imports ranged from $1.27 per pound in 1991 to $2.17 per pound in 1996. Changing the import mix of carcasses and cuts and fresh, chilled or frozen products does cause some per-pound valuation distortion. Cuts should have a higher value than

Figure 1. United States lamb and mutton imports as a percent of production.[a]



[a] Source: USDA, ERS, various years.

carcasses and fresh and chilled product should have a higher value than frozen product. Within the cuts, different cuts have different values (i.e., a loin will be higher priced than a chuck). The authors are not aware of the availability of cut level data on imported product.

Mutton Imports

Imports of mature sheep meat, or mutton, have been sporadic. In the early 1970s, total lamb and mutton imports were over 100 million pounds. The majority of the imported product was mutton. Subjecting mutton to the red meat import quotas caused imports to drop off dramatically. In recent years, mutton imports have ranged between 10.5 and 22.2 million pounds. In 1996, mutton comprised approximately 31.6% of the total lamb and mutton imported into the United States. Since 1990, mutton has accounted for an average of 33.6 % of all lamb and mutton imports.

Like lamb, imported mutton comes in both carcass and cut form. Mutton in carcass form accounted for 24.5 percent of 1996s mutton imports. While imported mutton can be fresh and chilled or frozen, frozen mutton accounts for around 99% of all mutton imports. This is not surprising given the fact that the estimated cost of shipping meat overseas is around $0.17 per pound by boat, the traditional method to ship frozen product. In comparison, it costs around $0.85 per pound to ship fresh and chilled product by airplane (U.S. ITC Pub. 2915, 1995).

Mutton imports also come primarily from Australia and New Zealand. Together, these two countries account for more than 98% of all lamb and mutton meat imports. In 1996, Australia was the source of 88% of the mutton imports while New Zealand accounted for 11%.

There is still some uncertainty as to mutton's use in the United States. Many speculate that the primary use is

Table 1. Quantities, values and estimated prices of lamb and mutton imports and exports (1990 through 1996).[a]

Year	1990, lbs. (ave. $/lb.)	1991, lbs. (ave. $/lb.)	1992, lbs. (ave. $/lb.)	1993, lbs. (ave. $/lb.)	1994, lbs. (ave. $/lb.)	1995, lbs. (ave. $/lb.)	1996, lbs. (ave. $/lb.)
Lamb Imports:							
Fresh/chilled	7,364,444 (1.65)	4,819,214 (1.69)	6,100,101 (1.75)	7,974,316 (1.86)	7,249,875 (2.08)	10,465,632 (2.41)	15,754,819 (2.64)
Frozen	16,074,228 (1.19)	18,968,093 (1.16)	19,043,074 (1.18)	30,196,729 (1.25)	29,151,353 (1.16)	29,820,976 (1.46)	30,379,449 (1.92)
Total	23,438,672 (1.34)	23,787,307 (1.27)	25,143,175 (1.32)	38,171,045 (1.37)	36,401,228 (1.34)	40,286,608 (1.71)	46,134,268 (2.17)
Lamb Exports:							
Fresh/chilled	1,257,424 (1.33)	1,016,288 (1.40)	1,062,619 (1.20)	696,197 (1.43)	1,526,734 (1.48)	355,648 (1.16)	90,514 (1.24)
Frozen	120,424 (2.16)	268,386 (1.58)	117,360 (1.87)	114,714 (2.25)	147,979 (2.03)	97,033 (1.96)	601 (1.52)
Total	1,377,848 (1.40)	1,284,674 (1.44)	1,179,979 (1.27)	810,911 (1.54)	1,674,713 (1.53)	452,681 (1.34)	91,115 (1.49)
Mutton Imports:							
Fresh/chilled	152,594 (0.70)	138,747 (0.63)	226,029 (0.49)	962,949 (0.57)	21,332 (0.71)	38,640 (0.75)	38,640 (1.17)
Frozen	15,298,015 (0.42)	14,181,284 (0.37)	22,015,034 (0.47)	10,689,636 (0.60)	10,572,623 (0.69)	20,099,883 (0.58)	21,308,596 (0.62)
Total	15,450,609 (0.42)	14,320,031 (0.38)	22,241,063 (0.47)	11,652,585 (0.60)	10,593,955 (0.69)	20,138,523 (0.58)	21,347,236 (0.62)
Mutton Exports:							
Fresh/chilled	1,973,677 (1.67)	3,900,919 (1.60)	2,477,803 (1.94)	1,872,337 (1.84)	1,767,890 (1.50)	1,464,269 (1.89)	895,649 (1.71)
Frozen	2,138,077 (1.26)	3,187,880 (0.97)	3,568,366 (1.02)	5,270,295 (0.88)	4,859,177 (0.92)	3,619,043 (1.20)	3,321,086 (1.13)
Total	4,111,754 (1.44)	7,088,799 (1.34)	6,046,169 (1.38)	7,142,632 (1.17)	6,627,067 (1.16)	5,083,312 (1.39)	4,216,735 (1.25)

[a] Quantity shown in "pounds;" values and estimates prices shown in "average $/pound."

in non-human consumables such as dog food. However, if dog food is imported mutton's use, it would not explain the incidence of fresh and chilled imports or why some imported mutton comes in cut form. Contact with various commercial sources over the past several years indicates that some of the mutton is being used for human consumption. Primary consumption may be in the growing ethnic population in the coastal areas.

The value of mutton imports has increased over the past several years. Imported fresh and chilled mutton imports hit the low price this decade in 1992 at $0.49 per pound. In 1996, imported fresh and chilled mutton was at the decade high of $1.17 per pound. The overall average price per pound for mutton has ranged from $0.38 to $0.69 per pound over the same period. However, there is some uncertainty about the reported values. Because the DOC determines values by collecting the information off the bill-of-lading, it is not clear if the total value is real or estimated by the shipping agent.

Live Animal Imports

Imports of live sheep and lambs peaked in 1989 when U.S. feeding interests brought in over 100,000 head from New Zealand. The drop in prices following 1989 saw live import numbers drop and hit the lowest point in two decades in 1991 at 23,217 head. However, since 1991, import numbers more than doubled to 47,648 head. The value of imported live animals has increased 355% from $1.55 million to $5.53 million. For the most part, live animal imports have accounted for less than 1% of slaughter and have not been a source of concern to the domestic industry. Since 1990, Canada has been the primary source of live sheep and lamb imports, accounting for more than 95% of all imported live animals.

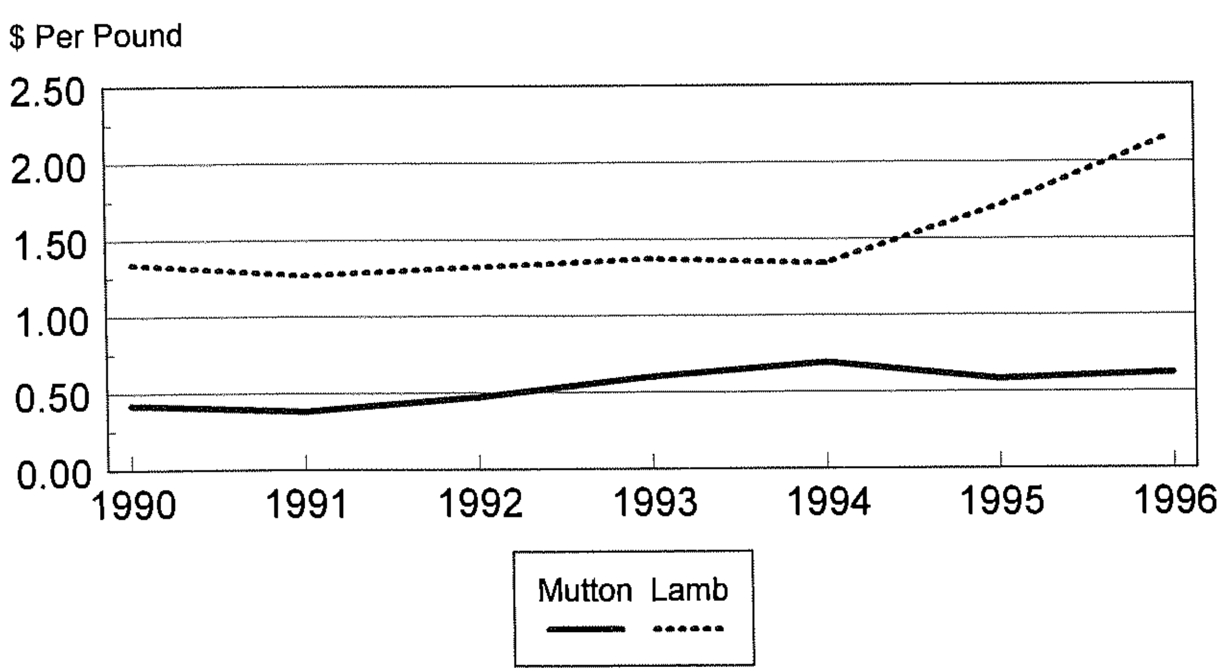
Exports

Exports of live animals and meat products from the sheep industry have not faced the same controversy as imports. This is possibly due to the fact that the U.S. is a very small exporter in terms of ovine products. The only recent controversy surrounding exports of lamb products was the period in 1995 through 1996 when China refused to accept sheep offal for processing due to the fear of scrapie contamination (ASI, 1996).

Exports of live animals had increased in the 1990s with Mexico becoming a major customer for U.S. live sheep. The majority of these sheep exports cross the border as slaughter sheep. After almost doubling between 1990 and 1993, exports dropped off dramatically in 1995 (Figure 3). Most of this decline was attributed to the devaluation of the Peso in December of 1994. With the recovery of the Mexican economy in late 1996, exports experienced some recovery. The only estimate of sheep export price elasticity known to the authors was -2.67 (Anderson, 1994). That estimate indicates that small changes in sheep prices are associated with relatively larger changes in the number of head exported.

With the decrease in sheep numbers, competition in the U.S. for animals

Figure 2. Average value of U.S. lamb and mutton imports (fresh, chilled and frozen).[a]



[a] Source: DOC, various years.

has increased. This is reflected in the per head value of exports increasing from the low $30 range in the early 1990s to slightly over $44 in 1996.

Lamb meat exports are a small portion of the U.S. market. With levels never reaching more than two million pounds, lamb exports account for less than 0.5% of domestic production. Exports throughout the 1990s have been limited to carcasses. Canada, Japan and Mexico are the only countries consistently represented as destinations for American lamb. No country stands out as the major destination. Some believe some percentage of lamb exports are due to cruise ship companies that using American lamb on their menu that export products to ports of call to reduce on-ship storage.

Due to the much higher volume, mutton exported from the U.S. actually goes to a greater variety of destinations than does lamb. However, unlike lamb, the countries that purchase American mutton are much more consistent. Over the last seven years, Mexico and Canada have been the primary destinations. Mexico alone accounted for around 50% of total exports on average. Total exports of mutton over the last seven years have averaged 42.6% of total domestic mutton production.

Conclusions

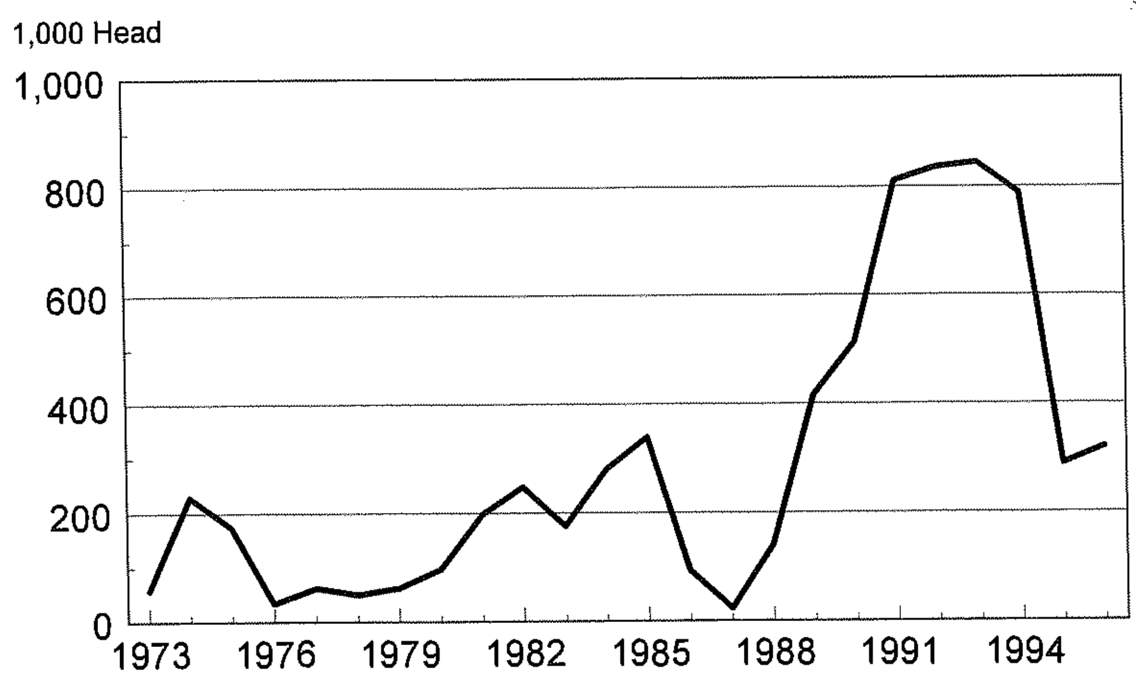
The domestic lamb and mutton markets have contended with imports for many years. Recently, imports have become a much more dominant force by comprising a larger share of the U.S. market. This is a trend that will most likely continue if the sheep industry in the U.S. continues to decline.

A question that remains is how imports effect domestic prices. The scarce economic research to date suggests that there is an imperfectly competitive relationship between domestic and imported lamb. Consumer attitude surveys indicate that the relationship is becoming much more competitive. Even if foreign lamb is not currently a perfect substitute for American lamb, it will probably become so as it takes up the larger share of the market and if Australia and New Zealand truly do increase their production of meat and dual purpose animals. Research into the domestic lamb market indicates that demand for lamb in the U.S. is inelastic. Therefore, even in an imperfectly competitive market, the imported product probably has a negative impact on the domestic price.

As imports grow and take a larger share of the market, the price effects will probably become more apparent. The decreased availability of domestic lamb combined with increased foreign lamb will most likely mute country of origin differences in consumers' minds.

Although it has been shown that domestic product can displace imported product at a higher rate than vice versa, domestic lamb prices may decline as more foreign lamb is imported. It is not clear that the domestic industry can compete at lower lamb prices caused by increased imports given the loss of wool price supports in 1993.

Figure 3. Live sheep and lamb exports (1973 through 1996).[a]



[a] Source: LMIC, various years.

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A Review of Direct and Niche Marketing of Lamb[1]

Tamra Kirkpatrick Kazmierczak[2]

Summary

The increased returns available to lamb producers when marketing through non-traditional channels has awakened the interest of many producers and producer cooperatives in direct and niche marketing. Direct and niche marketing are defined based upon the type of buyer and the characteristics of the product marketed. The enterprise characteristics of direct and niche marketers are briefly described. A distinction is made between the market outlets and quality niches available to lamb marketers. The promotion and advertising activities used to target these alternative markets are listed. The role of cooperatives in niche marketing is identified and critical issues for direct and niche marketers are discussed.

Key words: lamb, niche markets, direct markets, market outlets, quality niches, cooperatives.

Introduction

Direct and niche marketing of lamb are often mentioned by producers and farm advisors as ways to increase and/or stabilize fluctuating farm revenues from lamb production. *Direct marketing* is defined as "the activities involved in selling lamb and lamb products directly to the general public." *Niche marketing* is defined by "the special or unique characteristics of the lamb or lamb product marketed." In order to market lamb with these characteristics, niche marketers may either be targeting individual consumers or businesses such as retail food stores or restaurants as their final buyer (Kazmierczak and Bell, 1992a and 1995). In contrast, the term direct sales as used in the livestock industry refers to "selling livestock directly to packer buyers, order buyers and commission salesmen without going through an auction or an electronic market."

Despite the interest of producers in direct and niche marketing their lamb, little formal work has been reported on the subject. To the author's knowledge, only three publications have been written specifically on these alternative methods of marketing lamb. In order to reduce citations within the text and improve the overall readability of the article, these publications will be described briefly below.

Marketing Out of the Mainstream: A Producer's Guide to Direct Marketing of Lamb and Wool (Kazmierczak and Bell, 1992a) was written for individual producers interested in beginning or expanding direct and niche marketing activities for lamb and wool. This publication was based primarily upon on-farm interviews with direct marketers in four east coast states (MD, NY, PA, VA). Major topics included: 1) identifying and targeting market outlets for lamb and wool; 2) pro-moting and advertising direct market operations; 3) management of direct market operations; and 4) seven appendices including supplementary information useful to direct marketers of lamb and, to a lesser extent, wool.

Niche Marketing Opportunities Through Lamb Cooperatives (Kazmierczak and Bell, 1992b) was written for producer groups and cooperatives examining the possibilities of beginning or expanding efforts to market lamb to niche markets through cooperatives. This publication was based primarily on telephone interviews with seven cooperatives and producer groups across the country (MN, NM, NY, OR, UT, VT, VA). Major topics included: 1) a description of established and emerging cooperatives; 2) niche markets targeted or being explored by these groups; 3) cooperative marketing strategies; and 4) important issues in organizing a niche marketing cooperative for lamb.

Niche Marketing Guide for Lamb Cooperatives (Kazmierczak and Bell, 1995) was written as a guide to the specific marketing activities of cooperatives niche marketing lamb. This publication was based upon telephone interviews with ten producer groups and coopera-

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tives across the country (IN, MN, NM, NY, OR, PA, UT, VT, VA, WI). Major topics included: 1) marketing to specialty middlemen outlets; 2) marketing directly to consumers; 3) marketing to quality niches; 4) marketing value-added products; 5) marketing activities necessary to target these market outlets; and 6) critical issues faced by producer cooperatives striving to successfully market lamb.

These publications and two national marketing meetings (National Conference on Direct and Niche Marketing of Lamb and Wool, 1992 and 1996) were the result of work funded by the Rural Business-Cooperative Service[4] and the Agricultural Marketing Service divisions of the USDA and the American Sheep Industry Association (ASI). The national conferences (November 6-7, 1992, in Ellicott City, MD; September 20-21, 1996, in Sacramento, CA) covered a wide range of topics for both lamb and wool direct and niche marketing.

This article will draw from these publications and meetings to discuss: 1) the enterprise characteristics of direct and niche marketers; 2) the market outlets and quality niches for lamb; 3) the promotion and advertising methods used to target these markets; 4) the role of cooperatives in niche marketing; and 5) the critical issues which have been identified for direct and niche marketers. A brief conclusion notes some of the strengths and weaknesses of the three publications reviewed.

Characteristics of Direct and Niche Marketers

The enterprise characteristics of direct and niche marketers varied somewhat, because of the differences in targeted buyers. In general, direct marketers were individual producers and niche marketers with special or unique lamb products tended to be cooperatives with larger resource bases. However, some individual producers were able to successfully target many niche markets especially those producers located on the west coast of the United States.

Direct Marketers

Direct marketers of lamb had two marketing options, they could: 1) sell live lambs and help consumers arrange for their slaughter at a custom slaughter facility; or 2) slaughter the lamb themselves and sell cuts of lamb to the consumers. The first option was by far the most widely used because of the difficulties that producers incurred in meeting the federal/state meat inspection laws. Most producers delivered the live lamb to the custom processor for the consumer and some even picked up the processed meat for delivery to the consumer. However, the direct marketer sold the lamb on a liveweight basis and all billing was carefully documented to separate the fees owed the custom processor from the purchase price of the lamb. A few direct marketers were able to comply with federal/state inspection laws or contract with federal or state inspected facilities in order to sell processed lamb directly to consumers. However, because of the high cost of on-farm compliance with inspection requirements and the declining number of inspected facilities, few direct marketers were using this option.

Direct marketers of lamb were usually individual producers with small flocks and most of their farms were located near population centers which provided an opportunity for increased sales. These marketers mostly sold whole or half lambs and had worked with their custom processors to provide the consumer with options on the type of cuts received. Few, if any, special facilities were needed by these producers to direct market their lamb.

Direct marketers provided many more services to consumers and spent much more time interacting with the public than they would have if marketing their lamb through more traditional outlets such as auctions, teleauctions and computer sales. The time and monetary value of these direct marketing services were equated to those provided by middlemen in the more traditional lamb marketing channels and resulted in higher farm level returns for producers.

Direct marketers intensively managed the production, processing and marketing aspects of their businesses as a unit. They developed and then educated their customers on purchasing and slaughtering procedures. These procedures included: 1) estimating the yield of meat from a live lamb; 2) selecting options for slaughtering, cutting, wrapping and freezing; 3) establishing delivery procedures; and 4) deciding on billing and payment procedures. Most were one- or two-person operations and required great skill to juggle the production, customer service, meat inspection requirements, promotion/advertising, billing and bookkeeping aspects of their direct marketing business.

Niche Marketers

In general, individual producers on the east coast of the United States and throughout much of the country had difficulty meeting the volume, consistency and service requirements of most niche markets. However, regional differences in lifestyle, attitude, income and business climate resulted in more individual west coast lamb producers successfully targeting a variety of niche markets.

The majority of niche marketers interviewed for the publications were lamb marketing cooperatives. These organizations had between 9 and 100 producer members whose flock sizes ranged from 8 to 6,000 ewes and the cooperatives marketed between 10 and 100% of their members' lambs as a combination of whole carcasses, primal cuts and subprimal cuts.

None of the niche marketing cooperatives and only a very few of the individual producers owned their own slaughtering and processing plants. Instead most niche marketers contracted with other businesses that owned and operated federal- or state-inspected facilities. Most cooperatives and individual niche marketers did own some means of transporting the lamb carcasses and cuts from the slaughter facility to the buyers. Most cooperatives also provided their managers with a computer and software, but avoided the cost of office

[4] Formerly known as the Agricultural Cooperative Service and then as the Rural Business and Cooperative Development Service.

facilities by having their manager work out of his or her home. The majority of individual niche marketers were also computerized and worked out of offices located in their homes or on their farms.

Unlike individual niche marketers who accepted greatly increased marketing roles, producers that joined a niche marketing cooperative delegated responsibility for these marketing functions to the organization. The cooperative's manager had the responsibility to communicate with buyers, deal with customer service issues, make sure the group's lamb complied with federal inspection standards, conduct promotion and advertising activities and either perform the group's bookkeeping or oversee the process. The cooperatives required producer members to place lambs to be marketed through the organization in an inventory program so the manager could schedule the group's marketing activities. In many cases, members were required to weigh lambs regularly and keep the cooperative's manager informed of estimated finishing dates. Members then delivered lambs to the slaughter facility when instructed by the manager.

Identifying Market Outlets and Quality Niches

The market outlets available to direct and niche marketers of lamb were defined by the customer's identity, whether that be a home customer with a freezer or a buyer for a retail food store. In contrast, quality niches based upon special or unique product characteristics were available to direct and niche marketers within each of the market outlets.

Market Outlets

Market outlets that were identified included: 1) the freezer market; 2) the ethnic/religious market; 3) retail food store sales; 4) the restaurant market; 5) mail order sales; 6) mobile markets; 7) food service outlets; and 8) specialty distributors. The targeted customer, services provided, product offered, facilities needed and management considerations differed somewhat for each of these market outlets.

The *freezer market* targeted individual consumers in communities near the farm and could be serviced successfully with small flock sizes. Whole or half lambs were sold through this outlet. No special facilities were required on the farm for this outlet, but producers were willing to perform or arrange for: 1) delivery of lambs to slaughter facilities; 2) cutting, wrapping and freezing of the meat; 3) getting the packaged meat to the consumer; and 4) billing and maintaining records for the operation. A high degree of consumer interaction and education was required to target this market.

The *ethnic/religious market* targeted mainly individuals of middle eastern extraction of the Muslim and Jewish faiths and could also be serviced successfully with small flocks. In this case the whole lamb or sheep were often purchased for ritual slaughter commemorating a special holiday, feast or for special family occasions. Most producers provided a location with limited facilities where the customer could ritually slaughter the live lamb they purchased. These facilities ranged from an outdoor location with a tree, rope and water hose to an enclosed room with sink, chopping block and hanging hooks. The most critical aspect of this market outlet was the producers' willingness to learn and accommodate the special needs and customs of these customers.

Retail food store sales were difficult to target successfully because of the increased volume of lamb demanded, the frequent demand for primal and subprimal cuts and the exacting servicing requirements. Notable exceptions included several producers located on the west coast of the United States. Buyers for small local food chains, managers of individual retail food stores and specialized retailers with full-service meat departments were usually the contact people for this market outlet. These outlets often demanded higher quality meats to differentiate them from supermarkets and they often had the ability to break and package carcasses as primal and subprimal cuts. Producers or cooperatives targeting this outlet had to have access to federal/state-inspected slaughter and breaking facilities and refrigerated delivery equipment. Challenges encountered when marketing to this outlet included marketing cuts in proportion to their occurrence in the lamb carcass, providing consistent quality lambs and controlling costs so that both the producer and the retailer could earn a fair profit.

The *restaurant market* required mostly primal and subprimal cuts of fresh lamb. Individual restaurants did not use large quantities nor the same cuts of lamb so access to a large number of traditional and ethnic restaurants and frequent deliveries were critical to the successful targeting of this outlet. Access to federal/state-inspected slaughter and breaking facilities and refrigerated delivery equipment for route sales was necessary. Contacting and communicating with chefs in diverse restaurants, many of which spoke little or no English was a major problem for those targeting this market. Managing accounts receivable in an industry with a poor record of financial success was also a major challenge.

Mail order sales targeted home customers located over a wide geographical area. These consumers usually had to be educated on how to buy, store and prepare the lamb received. Whole carcasses, half-carcasses, quarter-carcasses and individual cuts were sold through this market outlet. Access to slaughter and breaking facilities providing federal/state-inspection were necessary when offering mail order sales. An advertising firm was usually needed to develop high-quality mail order brochures. In addition, excellent shipping procedures had to be developed because the freshness of lamb product and customer satisfaction were directly related to the timeliness and care with which the product was delivered. A quality mailing list was critical to success in this market outlet.

Mobile markets were moving units that were tried with some success to transport lamb cuts to concentrations of customers. These consumers were generally new or inexperienced lamb purchasers who had to be educated about lamb cuts and cooking procedures. Access to slaughter and breaking facilities providing federal/state-inspection was necessary for the resale of lamb through this market outlet. The refrigerated delivery vehicle and some type of mobile display stand were all the equipment required. The biggest challenge in targeting this outlet was determining and complying with health regulations, legal restrictions and licensing requirements.

The *food service outlet* encompassed a wide variety of large often nationwide organizations. These organizations included casual and theme restaurants, cafeterias, hotel and motel restaurants, health care facilities, fast food chains, education facilities, military complexes, transportation providers, detention facilities and retail food warehouses (American Lamb Council, 1990). Specific cuts of lamb were generally demanded by buyers for each type of organization. These market outlets required access to federal/state-inspected slaughter and breaking facilities. Food service operators had extremely specific standards for the product they purchased and would not tolerate variations in portion size, quality or packaging. They required large volumes of this standardized product and were very price sensitive.

Specialty distributors provided well-defined unique product characteristics and/or convenience aspects to individuals or businesses. The cuts of lamb demanded and the facilities and resources required to target these markets varied, but all required access to federal/state-inspected slaughter and breaking facilities. Examples of these distributors included established mail order catalogues, gourmet restaurant purveyors and natural food store distributors. Although these outlets paid premium prices, they were limited in number, were highly competitive, handled limited volumes, demanded the highest quality product and most would not purchase the whole lamb.

Quality Niches

Quality niches existed within specific market outlets based upon special or unique product characteristics that were of value to the consumers and buyers within each of the outlets. The quality niches identified included: 1) lean meat; 2) organic certification; 3) gourmet palatability; 4) halal and kosher certification; and 5) regional identity.

The demand for *lean meat* and low-fat products by consumers had become more important to consumers within the United States. Altering production methods, processing practices and quality control procedures resulted in lamb with these low-fat characteristics. Federal grading and the ASI Certified Fresh American Lamb program provided measures of leanness that assured buyers of the low fat qualities of the product. Although lean meat often commanded price premiums, market outlets willing to pay these premiums had to be developed.

The terms *"natural," "organic" and "chemical-free"* were used to denote a quality niche where animals were fed only food that had not been treated with pesticides and chemical sprays and/or had not been given growth hormones, antibiotics and drenches. Consumers purchasing organic meat were concerned that modern production practices affected the wholesomeness of their food and therefore their own health. While most consumers demanding an organic product were willing to pay price premiums, price remained an important factor. Organic certification was a rapidly changing area when the reviewed studies were being conducted and both the USDA's Food Safety and Inspection Service and the USDA's Agricultural Marketing Service were beginning to adopt standards that would identify and regulate to this quality niche.

Gourmet palatability was demanded by a small subset of lamb consumers who were more sensitive to the quality characteristics of the meat than to the price. Handling procedures which affected the palatability or perception of palatability had to be state-of-the-art to target this quality niche. These procedures included slaughtering, cutting, deboning, packaging, labeling, freezing and shipping. As a result, establishing quality standards and developing the operating procedures to meet these standards in the slaughter and breaking facility were crucial to the successful targeting of this niche.

Halal and kosher certification were used to identify lamb that met the slaughter and handling requirements of the Muslim and Jewish faiths, respectively. In general, it was easier to meet the less stringent requirements of Islamic halal meat. To qualify for the halal designation the head of the lamb or sheep had to be turned toward Mecca, Saudi Arabia, and the slaughterer had to say a specific prayer before quickly slitting the animal's throat. All blood had to be drained out of the animal before it could be butchered.

In contrast, the kosher slaughter of lamb or sheep had to be performed by a believing Jew, usually a Rabbi or a person with written authorization from a rabbinical authority. This person had to be knowledgeable in the ritual laws of slaughtering as even the condition of the knife used in the slaughter was important to the process. The slaughterer had to quickly sever the animal's trachea and esophagus and then inspect the carcass before it could proceed through the kosher process. All visible and many perceived imperfections in the carcass and especially the lung cavity were grounds for kosher rejection. As with the halal process all blood had to be allowed to drain out of the carcass before it could be butchered.

Regional identity was a quality niche promoted by many states to give local agricultural products an image of freshness and quality that could not be achieved by similar products shipped from distant areas or countries. Many consumers were willing to support these efforts if the quality standards of local products met or exceeded that of products produced elsewhere. Criticisms about inappropriate product standards, the lack of quality standards and the lack of enforcement procedures did affect producers' and cooperatives' willingness to participate in such programs.

Promotion and Advertising

Examples of promotion and advertising activities used by direct and niche marketers were detailed in the publications as avenues of communication with potential customers. Advertising was defined as "the purchased time or space in newspapers, magazines, radio and television." Promotion was defined as "the activities which expose the product to the individual consumer in direct marketing outlets or the buyer or consumer in niche marketing outlets." Correctly identifying and understanding the customer was critical to establishing an appropriate message and a successful marketing program which integrated both advertising and promotional activities. The goal of a marketing program was to increase the visibility, acceptance and quantity sold of a specific product.

Of the specific promotion and advertising methods used to target direct marketing outlets, word-of-mouth advertising was noted by direct marketers to be one of the most effective methods. Although this advertising was not purchased, it had to be earned by producers through constant courteous service and a consistent quality product. Other methods used to target direct marketing outlets included signs, direct mailings, newspapers, consumer guides, demonstrations, festivals/fairs, promotional leaflets, educational materials, joint promotions with other products, school tours of farms, coupons, mail order brochures, magazines, labels, logos, news releases, radio and television.

The promotion and advertising activities used to target niche market retailing outlets included personal sales calls, quality guarantees, samples, promotional leaflets, brokers, food shows, product delivery services, branded products/labeling, in-store demonstrations, point-of-purchase materials, coupons and joint promotions. Of these, frequent personal sales calls helped continually convince buyers of the unique qualities of the product, helped resolve any problems the buyer encountered in marketing the product and helped keep the niche marketer in touch with consumer reactions to their product.

Role of Cooperatives in Niche Marketing

Niche marketing cooperatives for lamb represented a significant departure in the traditional role that cooperatives have played in the sheep industry. The objective of these producer-owned, producer-operated and producer-patronized businesses was to allow producers to obtain higher returns for their lamb by pooling their sales volumes and financial resources. Through pooling, niche marketing cooperatives were able to provide specialized marketing services which often were not previously available in their areas. Some of the most notable services of niche marketing cooperatives to their producer members included: 1) the access to full-time or increased-time managers to handle marketing; 2) the access to better contracts with slaughtering and breaking facilities; 3) the lower marginal costs for inspection, grading and certification programs; and 4) the greater potential for developing economically feasible value-added products.

Although many cooperatives had intended to use their increased resources to increase producer returns through value-added lamb products, few had been financially successful in their efforts. Examples of value-added lamb products included fresh and smoked sausages, lamb-filled breadsticks, lamb stew, processed seasoned cutlets, highly seasoned hors d'oeuvres, marinated shish kabobs and smoke-cured legs. Many of these products were favorably test marketed at food shows, festivals and fairs, but the production costs and the time required to gain widespread market acceptance was greater than the cooperatives had anticipated. This remained an area of concern to cooperatives because value-added products were becoming more prevalent in the meat industry and commodity groups not keeping pace were losing their market share.

Critical Issues for Direct and Niche Marketers

Direct and niche marketers faced a number of challenges in operating a financially successful business. Direct marketers struggled most with customer interaction issues and the availability of quality slaughtering and fabrication services. Niche marketers were most challenged by a limited knowledge about the requirements of the traditional meat marketing system beyond the farm gate and the underestimation of the capital and time required to develop and gain market acceptance for value-added products. The challenges to both direct and niche marketers covered in the reviewed publications included: 1) customer service and buyer satisfaction; 2) product differentiation considerations; 3) slaughter and fabrication availability; 4) management requirements; 5) cooperative capital requirements; and 6) cooperative member issues.

Conclusions

The existing literature can help clarify the thinking of producers and cooperatives interested in alternative methods of marketing lamb by offering definitions for direct and niche marketing as well as classifying specific market outlets and quality niches for lamb and lamb products. The wide diversity of these outlets and quality niches demonstrates a potential market for lamb that has not been fully tapped in many areas of the country. The challenge to direct and niche marketers is to increase the awareness of current and potential lamb consumers to the quality lamb products available from domestic producers. The grass-roots focus of direct marketers, and many niche marketers, can help slow and even reverse the tide of decreasing lamb consumption in the United States.

While alternative markets for lamb obviously exist, the consumers and buyers targeted by direct and niche marketers are not homogeneous. Their heterogeneous nature can be inferred by the diversity of market outlets, quality niches and promotional and advertising methods. More research on the effectiveness of specific promotional and advertising methods, and the reasons why they work within specific market outlets and quality niches, would substantially reduce the financial risk of direct and niche marketers and help them to use their limited resources more effectively. Such research has the potential to increase farm revenues from lamb, decrease the risk of direct and niche marketing lamb producers going out of business and perhaps change the declining trend in domestic lamb consumption by maintaining or increasing the supply and visibility of high-quality domestic lamb.

In the meantime, direct and niche marketers can guide their efforts to target non-traditional market outlets for lamb by utilizing not only the publications reviewed here, but also information obtained at meetings of the North American Farmers' Direct Marketing Association (NAFDMA; 1997) and from the general literature on direct and niche marketing. Although much of this larger body of literature does not address the unique problems of perishable products, some of the literature does focus specifically on agricultural products, such as the recent publication by Gibson (1994). Publications based upon primary data from direct and niche marketers, such as those reviewed in this article, will be the most useful. However, the geographical diversity of markets and marketers must be taken into consideration when evaluating the usefulness of each publication, because the experiences, successes and types of direct and niche markets targeted may vary substantially by region.

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The Relation of Slaughter and Carcass Weights to Production and Processing Efficiency and Market Acceptability

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Summary

Increases in lamb weights and decreases in lamb numbers since 1960 have been accompanied by a dramatic drop in U.S. lamb consumption. The heavier weights have resulted in increases in fat thickness which exceed the depths recommended by the American Sheep Producer Council's Consumer Acceptability Task Force. Reasons for these changes are related in part to producer and feeder profit at heavier weights. Maximum profit occurs when the cost of an added pound of gain equals the price of a pound of lamb. But this may not occur until after lambs reach heavy weights and fat thickness has become excessive. Weight and fat depth are controlled when packers begin to discount for extremely heavy lambs but packers are hesitant to discount because their profit margins also increase with increasing lamb weight. This results from lamb dressing percentages increasing and slaughter costs per unit weight decreasing as lambs become heavier. Fat depth and weight might be controlled if yield grading were used more in marketing lamb. Purveyors and retailers benefit from heavier lambs especially if they are not excessively fat because labor (minutes/cwt) to cut and trim heavy carcasses declines as carcass weight increases. Disadvantages from a purveyor or retailer standpoint include increases in trimming time and decreases in trimmed cut yield which occur when heavy lambs are excessively fat. Decreased consumer demand for lamb counters the production and processing efficiencies of heavy, fat lambs. Almost every consumer study in the last decade shows that cuts of lamb offered to the consumer are too fat. Therefore, some consumers may avoid buying lamb even though palatability does not decrease with increased weight and fatness. Until consumer preferences for leaner lamb are captured in the price incentives offered to lamb producers and feeders, excessively heavy lambs will continue to be produced. The solution is for producers and feeders to work toward generating premiums sufficient to encourage lean lamb production.

Key words: lamb, weight, fatness, processing, production.

Introduction

Average carcass weights of U.S. sheep and lambs increased from 47 to 63 pounds between 1960 and 1988 (TAMRC, 1991), but have remained relatively constant since 1988 (USDA Economic Research Service [ERS], various years, a). Over the 1960 to 1988 time period sheep and lamb numbers declined from 33 million head to 10 million. Since 1988 numbers have further decreased to 8 million head (USDA, 1997). Increases in lamb weights and decreases in lamb numbers have been accompanied by a dramatic drop in U.S. lamb consumption. Annual per capita consumption of lamb and mutton on a carcass basis dropped from 5.1 to 1.2 pounds between1960 to 1996 (USDA/ERS, various years, a,b).

The purpose of this article is to examine the underlying motivations for the changes that have taken place and to evaluate the influence of weight on production and processing efficiencies and on consumer acceptance of lamb.

Production Efficiency

A discrepancy between current slaughter weights and published optimal slaughter weight guidelines for lamb exists. If the optimal fat thickness for slaughter lambs is 0.10 to 0.25 inches, as suggested by the American Sheep Producer Council's Consumer Acceptability Task Force,

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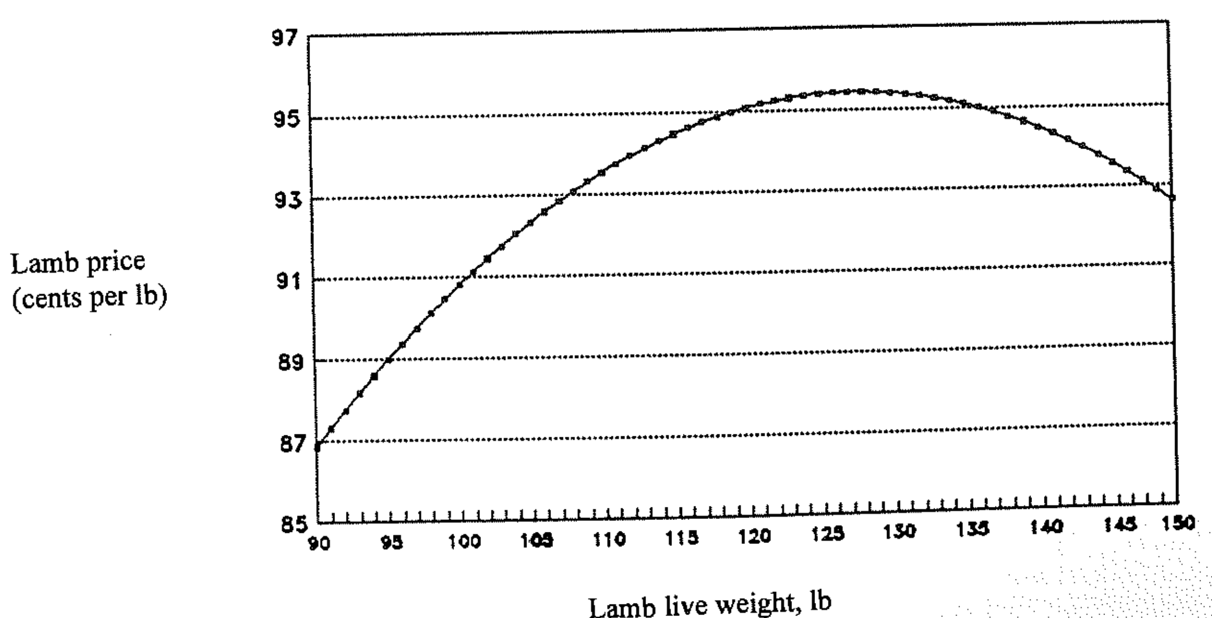
then results of the Baird et al. (1988) study indicate that small-, medium- and large-framed lambs should be slaughtered at weights between 80 and 120 pounds, 90 and 125 pounds and 90 and 140 pounds, respectively. Target weights corresponding to the midpoint of the desired finish of 0.18 inches are 104, 111 and 122 pounds, respectively, for small-, medium- and large-framed lambs. In another study, Snowder et al. (1994) showed optimal slaughter weights for certified lean lamb carcasses of Targhee, Rambouillet and Polypay wethers to be 99 to 103 pounds while those of Columbia wethers were 99 to 121 pounds. Optimal slaughter weights recommended by these two studies are lighter than current average slaughter weights of 127 pounds (ASI, 1996). It is clear that weights vary considerably by management, lamb frame size and season of the year. From February to May, feedlot lambs are often slaughtered at average weights of 140 to 150 pounds. Tatum et al. (1988) believe current slaughter weights are too high. Almost 60% of the carcasses in their national survey were 60 pounds or above and about 40% of this sample had yield grades (YG) of YG-4 or YG-5. It is possible that between the time of the Tatum et al. (1988) survey and the present, the percentage of excessively fat lambs have decreased because a greater awareness of over-finished lambs may have resulted from the 1992 lamb grade change that required all lambs to be yield as well as quality graded (USDA, 1992).

Information developed by Steve Meyer (personal communication), shows that the optimal lamb slaughter weight to achieve maximum pricing is 125.6 pounds (Figure 1). However, in the absence of significant discounts for fat, the maximum profit per lamb occurs when the cost of an added pound of gain equals the price of a pound of lamb. This may not occur at the point of maximum pricing. The feed conversion efficiency of the lamb is an important profit consideration. However, research cited below indicates that lamb growth rates and feed efficiency remain favorable for larger framed lambs at well above optimal weights. As a result, optimal weight in terms of producer profit often occurs at the point at which packers begin to discount for extremely heavy weights. This is generally much higher than the optimal weights previously cited. The discounted weight may vary by packer. Packers fabricating carcasses into trimmed cuts often start discounting at lighter weights than packers selling intact or 3-piece boxed carcasses. Discounts for heavier weights most often occur from February to April when average slaughter weights peak.

Incentives for producers to market lambs at lighter weights than the point at which packers start discounting are minimal. Heavier lambs mean more pounds of lamb marketed per ewe and the costs to feed and care for the ewe flock are the same regardless of the weight of the lamb sold. According to Shelton (1980) the most important means of improving efficiency from the standpoint of the individual ewe is to increase the weight of lamb produced.

Figure 1. Relationship between lamb price and live weight (1994 through 1996).



This may be accomplished by the sale of more lambs or larger lambs (Hogue, 1968). Because the more prolific breeds are smaller, some believe more lambs is the best way to increase amount of lamb produced. However, production of heavy lambs from the smaller more prolific breeds would only increase the fatness problem.

Feed and Rate of Gain Efficiency

Shelton (1980) and Black and Griffiths (1975) have cited several studies showing that feed per pound of gain increases as lamb weight increases. In addition, Ross (1989) indicates pounds of feed per pound of gain increases and daily gain decreases with increases in fat depth. The findings support those of Beermann et al. (1995) who concluded that slaughtering at appropriate weights in contrast to excessively heavy weights can improve rates of gain and efficiency of nutrient use 10 to 20%. In another study, the economic feasibility of feeding lambs to heavier slaughter weights was explored by Harrison and Crouse (1978). Ram lambs produced by mating Suffolk rams to one-half Finnish-Landrace ewes were fed high-energy diets under simulated price and cost conditions. The ram lambs generated profits at weights of 154 pounds and above, but highest net returns were obtained at 143 pounds. Optimal slaughter weights for ewe lambs of similar breeding were generally about 11 pounds lower than for ram lambs. Feed efficiency and rate of gain decreased as weight and time on feed increased up to 212 days on feed and up to 154 pounds live weight. The greatest decrease in feed efficiency and rate of gain came after lambs reached 142 pounds.

Ferrell et al. (1979) found that feed efficiency in Suffolk-cross lambs fed a high concentrate diet and slaughtered from 119 to 145 pounds changed from 4.9 to 5.3 pounds per pound of empty body gain but live weight gain was similar for the different weight groups. When Suffolk-cross lambs were fed 20% rolled barley, 20% rolled oats and 58.5% alfalfa, rate of gain remained constant at 120, 130 and 140 pounds, respectively (Dahmen et al., 1987). Feed efficiency was 6.6, 7.3 and 7.7 pounds of feed per pound of gain for the 120-, 130- and 140-pound lambs, respectively.

Virtually all lamb feedlots utilize high-concentrate diets and those the authors visited with reported satisfactory rates of gain for large framed lambs fed up to 145 pounds. Utilization of high-concentrate diets probably explains why rates of gain in large-framed lambs usually remain constant at higher slaughter weights. Ferrell et al. (1979) reported that lambs gained 0.40, 0.51 and 0.55 pounds per day and required 144, 119 or 105 days to reach slaughter weight on the low-, medium- and high-concentrate diets, respectively. Garrett et al. (1971) and Clanton and Woods (1966) have obtained comparable results in cattle. One additional reason for the high rates of gain for large framed lambs fed up to 145 pounds live weight is that the majority of the feedlot lambs are only fed for 30 to 60 days prior to slaughter (Tatum et al., 1988). Some 145 pound lambs are not excessively fat at slaughter. However, in 1988 only 29% of all feedlot lambs qualified for the American Sheep Producer's Council lean designation (Tatum et al., 1988).

Changes in fatness and weight distribution of lambs over a 20-year period are compared in Table 1. Even with selection emphasis on large-framed lambs, very little change in fat depth at similar carcass weights has taken place. What has occurred is a change in weight distribution. In the 1988 survey approximately 60% of the carcasses sampled weighed 60 pounds or more while in the 1967 and 1967 through 1968 surveys less than 25% of the carcasses were over 60 pounds.

Changes related to production efficiency over the 20-year period include selection emphasis on larger framed sheep and a greater percentage of the slaughter lambs being fed high-concentrate diets. Feedlot lambs represented 82% of the sample in the 1988 survey compared to less than 50% 25 years ago. Shelton (1980) cautioned that productive efficiency as discussed in the preceding section is not always synonymous with economic efficiency and economic efficiency is a higher priority for producers. Practices geared to take advantage of low-cost feeds, seasonal price peaks and reduced labor demands are often favored over maximum productive efficiency.

Table 1. Changes in lamb carcass weight distribution and in fat depth from 1967 to 1987.

	Year					
Pounds	N	1967[a]	N	1967-68[b]	N	1987[c]
up to 45	235	0.13	1,605	0.22	201	0.13
45 to 50	485	0.15	1,218	0.26	279	0.17
50 to 55	552	0.18	1,084	0.28	1,012	0.20
55 to 60	492	0.20	532	0.30	1,050	0.24
60 to 65	328	0.23	486	0.31	1,303	0.26
65 to 75	212	0.26	358	0.34	1,676	0.31
75 and up	22	0.32	69	0.41	668	0.36

[a] Southam (1968), N = 2,326 lamb carcasses in the Rocky Mountain region.

[b] Tuma et al. (1968), N = 5,352 lamb carcasses in the midwest and east.

[c] Tatum et al. (1988), N = 6,224 lamb carcasses throughout the United States.

Producer Profitability

Blackburn et al. (1991) confirmed that higher slaughter weights can increase net feedlot returns using a simulation of lean lamb production systems. Their study evaluated the effects of mature size, nutrition and target weight on carcass composition and net returns. Lambs produced by sheep of large mature size, fed a high-concentrate diet and slaughtered at 143 pounds were most profitable even though feed efficiency and growth rate were decreasing at the time of slaughter. According to Blackburn et al. (1991), as the ratio of sale price to purchase price declines, increases in slaughter weight takes precedence over biological considerations to maximize profit margins. Pricing slaughter lambs on a lean basis using indicators such as YG would counteract heavier weights. In spite of the increased profits of large-framed lambs in the feedlot, the advantage may not apply to the entire sheep production system because increased weight of output is counterbalanced by more input for maintenance and growth (Wang and Dickerson, 1991). Therefore, larger sheep are not necessarily more efficient under all production systems.

Processing Efficiency

Much of the increase in slaughter weights and the increase in percentage of high-concentrate fed lambs has been driven by the packer whose profit margin increases with an increase in lamb dressing percentage. For every 125 pounds of live lamb purchased, the packer has 2.5 additional pounds of lamb carcass to sell when dressed yields increase from 50 to 52%. Heavier slaughter weights and higher levels of concentrate feeding increase dressing percentage (Field et al., 1971). While dressing percentages of 49 to 51% were common 25 years ago (Field et al., 1971), dressing percentages in today's heavy feedlot lambs shrunk 4% are often 52% or higher with the kidney fat out. Large-framed slaughter lambs fed a high-concentrate diet and slaughtered at 145 pounds yielded 53.84% in one study (Field et al., 1992). In another study, 65-pound lamb carcasses made up 53.6% of the live weight and lambs expressing the callipyge gene yielded 57.4% (Field et al., 1996). Some progress at decreasing the emphasis on dressing percentage, and the indirect emphasis on heavier and fatter lambs, can be made by encouraging sales on a carcass basis instead of a live basis and by encouraging YG pricing.

In addition to improved dressing percentages, slaughter costs per unit weight to process heavy lambs are lower than for lighter lambs. Botkin et al. (1988) gave an example of a packing plant that dressed 4 lambs per worker hour and another plant that dressed 7 lambs per worker hour. Theoretically, an increase of 16 pounds in lamb slaughter weight would result in 64 and 112 pounds more lamb being dressed per worker hour at the plants processing 4 and 7 lambs, respectively. This is because in most instances slaughter chain speeds are the same for lots of lambs of different weights. Nevertheless, in view of the problem of excess fatness accompanying heavy slaughter weights, processors should concentrate on increasing line speeds through automation rather than on slaughtering heavier lambs to decrease processing costs per unit. In addition to slaughter costs, costs to buy, truck and sell heavier lambs are nearly the same as those for lighter lambs. Another small advantage of the heavier lambs is the larger pelt size. Tanners pay more for pelts with a larger surface area from heavy lambs when compared to those with a smaller area from lighter lambs because of decreased tanning costs per square foot of pelt and higher yields.

Retailers also profit by processing heavier lambs, especially if they are not excessively fat. Lorenzen et al. (1997) have published results from a study used to develop a computer assisted retail decision support (CARDS) software package that makes it possible to quantify the relationship between carcass or cut weight and finish with labor requirements. Time required to perform boneless or semi-boneless processing procedures increases labor costs and cost of retail cuts per pound when compared to time for making bone-in cuts (Table 2). Labor in minutes/cwt and total labor time to split, cut, trim retail cuts and trim lean decline as carcass weight increases from 55 to 65 pounds. Once carcass weights reach 75 pounds, more total labor time to cut each carcass is required but total labor time expressed as minutes/cwt is still lower when compared to 55-pound carcasses. It takes approximately 5 minutes longer to trim retail cuts and lean from YG-4 carcasses than from YG-2 carcasses regardless of carcass weight. Retail yield estimates from the CARDS package were similar within YG for 65- and 75-pounds carcasses but estimates for 55-pound carcasses were higher. Therefore, the higher retail yield of lighter lambs partially offsets the lower labor requirements for heavier lambs at the retail level.

Table 2. Fabrication time to make bone-in retail cuts of lamb stratified by carcass weight and yield grade.[a]

	55 pounds		65 pounds		75 pounds	
Labor, minute/cwt	**YG-2**	**YG-4**	**YG-2**	**YG-4**	**YG-2**	**YG-4**
Splitting	6.48	5.79	5.08	4.49	5.71	5.20
Cutting	15.75	11.23	10.15	6.33	14.22	10.90
Trimming	36.29	44.68	26.94	34.03	28.13	34.28
Lean trimming	13.28	15.82	10.67	12.81	10.32	12.18
Total time	71.80	77.52	52.84	57.66	58.38	62.56
Retail cut yield, %	80.9	70.3	75.8	66.8	75.0	67.1

[a] The Texas A&M University CARDS software package was used to determine fabrication times. All retail cuts were trimmed to 0.12 inches of external fat as described by Lorenzen et al. (1997). Retail cuts included: arm chops, blade chops, dinner ribs, rib chops, Denver ribs, loin chops, sirloin roasts, center leg roasts, shank half leg roasts and lean trim.

The minimal differences in cutting time for lamb carcasses of different weights is supported by the constant speeds at which commercial lamb fabrication lines run regardless of the weight of the lambs being cut. Overall, heavier lambs can be processed from slaughter to retail cuts more efficiently than can lighter lambs. It is clear that the packer, feeder and producer have all benefited from increases in lamb weight if declines in consumer demand for lamb are not considered. Retailers have benefited in terms of labor in minutes/cwt but some decreases in carcass retail yield have occurred.

Market Acceptability

The production and processing efficiencies discussed previously for heavier lambs are minimized because heavier lambs are usually fatter. Hammond's classic studies of the patterns of tissue growth in sheep clearly demonstrate that increasing rates of fat deposition occur with increasing weight (Hammond, 1932). According to Reid et al. (1968), the effects of age of animal on carcass composition are marginal. If lambs on a restricted diet are kept until they reach the same weight as lambs on full feed, they will have about the same fat content provided they are the same frame size and sex. Reid's data show that body weight accounts for 88 to 95% of the variance in total body fat. Therefore, our discussion on market acceptability will focus on lamb weight. Nevertheless, we realize that it is possible to manipulate the body composition of heavy lambs (Glimp and Snowder, 1989; Blackburn et al., 1991; Beermann et al., 1995). Heavier leaner lambs could meet production and processing efficiencies while satisfying consumer demand if they were available in large numbers. Unfortunately, most heavy lambs are too fat.

Consumer Tastes and Attitudes

The over-fatness problem as it relates to weight has existed for several years and the problem has worsened with the increases in weight previously discussed (Table 1). According to Tatum et al. (1988), today's 60- to 65-pound lamb carcasses have 0.26 inches of fat over the longissimus muscle at the 12^{th} rib. Recall that external fat thickness of 0.10 to 0.25 inches was recommended by the American Sheep Producer Council's Consumer Acceptability Task Force. The conclusion that lambs being marketed are too fat is also supported by a study of Jeremiah et al. (1993). They presented a random array of untrimmed chops representative of four slaughter weight groups to 2,002 consumers as they passed through 31 supermarkets in two cities. Respondents had an aversion to fat and over 50% indicated the chops were unacceptable. Even when chops are trimmed consumers believe some cuts are too fat.

Researchers at the University of Wyoming trimmed loin chops, leg roasts and arm chops from 50 lambs averaging 0.27 inches of fat over the longissimus muscle to 0.10 inches of subcutaneous fat and asked lamb consumers to score the cuts for leanness when the packages were opened and cooked (unpublished). Scores of "too fat" were assigned to 9, 10 and 23% of the loin chops, leg roasts and arm chops, respectively. We believe that a higher percentage of arm chops were assigned a "too fat" score because arm chops contain more intermuscular fat than the other cuts. The rib is the fattest of the major wholesale cuts of lamb (Field, 1962) and the large end of the rib is much fatter than the small end. Field et al. (1993) have reported that 21.4 to 25.8% of the dissected 6^{th} and 7^{th} rib is intermuscular fat. If 6^{th} and 7^{th} rib chops had been presented to consumers in the unpublished University of Wyoming study, scores of "too fat" may have been assigned to more than 23% of the chops. In the case of large end rib chops and blade chops the intermuscular fat cannot be trimmed without destroying the cut.

The 1996 Attitude, Awareness and Usage Study conducted by the GMA Research Corporation in Bellevue, WA, for the American Sheep Industry Association's Lamb Council was done via telephone calls to approximately 800 participants in 32 metropolitan markets where there is a higher availability of lamb at both retail and food service. The participants had to be the chief household shopper and a non-vegetarian in order to participate in the survey. Retail users were those who ate or served lamb at home at least once in the past year. While the majority of the retail users interviewed said they were satisfied with the lamb selection at their grocery store, 30% were not satisfied and 7% said lamb appeared fatty (Gerhard, 1996). Other dissatisfied retail users said there are too few cuts and limited choices. More than one in four indicated they cannot always count on their store to carry lamb and 16% expressed concern about the quality of lamb.

Purcell (1995) discussed economic issues and potentials in lamb marketing. He believes the decline in demand for lamb lies in increasing consumer concerns about fat and increasing demands for consistent quality and convenience in preparation. According to Purcell (1995) it is the producers that are concerned about the long-range viability of their industry and it is the producers that will have to prompt the needed changes.

In 1991 the Texas Agricultural Market Research Center (TAMRC) Lamb Study Team evaluated the strengths and weaknesses of lamb marketing by interviewing 25 feeders, 12 packers, 23 breakers, 30 non-breaking wholesalers, 29 retailers and 26 food service groups from across the country. The key marketing problems cited by the survey respondents included problems related to overly fat lamb. Fat lamb as a food was considered a problem by 25%of the feeders, 20% of the packers, 7% of the breakers, 4% of the non-breaking wholesalers, 12% of the retailers and 6% of the food service groups. Packers (42%) considered liveweight variability a problem and 24% of the breakers and 14% of the non-breaking wholesalers listed light lambs as a problem. But only one individual out of all the interviews conducted mentioned that lambs were too heavy. Apparently some in the lamb industry recognize excessive fatness as a problem and light lambs as another problem but they do not recognize the positive relationship between fatness and slaughter weight. If more in the industry recognized the relationship between weight and fatness, they would consider light lambs less of a problem.

A potential advantage of 66- versus 50-pound lamb carcasses was tested by Southam and Field (1969). They placed cuts from each weight group in counters of retail stores. Consumers selected rib and loin chops from 66-pound carcasses over similarly finished rib and loin chops from 50-pound carcasses by a ratio of approximately 6-to-5 but leg roasts from 50-pound carcasses were selected by a ratio of approximately 3-to-1 over leg roasts from 66-pound carcasses. Therefore, the larger area of longissimus muscle in chops from heavy lambs appealed to more consumers but the heavier legs were a disadvantage. A larger longissimus muscle in loin chops is also a disadvantage if the larger chops have more fat than their smaller counterparts. Jeremiah et al. (1993) concluded that consumers were willing to accept very small chops with a relatively high proportion of bone, providing they contained a very low proportion of fat. They concluded that for lamb to retain its market share much leaner animals must be produced and marketed.

The effect of weight on lamb flavor was reviewed by Crouse (1983) who concluded that no discernible trends in meat flavor associated with weight existed. Furthermore, Field et al. (1983) found little evidence that fatness has any influence on market lamb flavor. Jeremiah et al. (1995a,b) reported palatability attributes and consumer acceptance of roasts from 1,678 lambs varying in live weight from 70 to 169 pounds. Flavor intensity generally increased with increases in slaughter weight but flavor intensity decreased with increasing weight in older ram lambs. Differences in consumer acceptance of flavor among the weight groups were small and the magnitude of the flavor differences were of marginal practical significance. Smith et al. (1976) reported that heavier carcasses with greater amounts of subcutaneous fat chilled more slowly and maintained muscle temperatures conducive to autolytic enzyme degradation for greater periods of time postmortem. Hence, heavier carcasses were more tender than lighter carcasses. In addition, Jeremiah et al. (1995a) found that shear force values decreased and panel tenderness scores increased as slaughter weight increased in ewe and wether lambs slaughtered at ages up to 15 months and weights up to 169 pounds. It is clear that increasing carcass weight does not detract from palatability of lamb but it does detract from consumer acceptance when the cuts are excessively fat.

In view of the small number in the lamb industry who consider fat lambs a problem – and the even smaller number who think that lambs are too heavy – the ability of producers who are concerned about the long-range viability of their industry to prompt needed changes must be questioned. Because the long-term viability of the lamb industry is at risk, a better understanding of the underlying reasons for the decline is needed. In addition to excessive fat, other factors (i.e., relative retail price of lamb in relation to other meat, a decline in consumer demand for red meat and increasing consumer demand for consistent meat quality) need to be considered.

Conclusions

Because consumer preferences for a leaner lamb product are not sufficiently captured in the price incentives offered lamb producers, processors and feeders, heavier and fatter lambs are being produced. In large measure it's because higher profits can be made by producing and processing heavy lambs that are often over-finished. Heavy lambs return more per ewe to the producer, are more profitable for the feeder and are more efficient to process but the increased profits may be relatively small when compared to the increased costs associated with further declines in sheep numbers. Consumers are getting lamb that looks fatty and is relatively expensive. Even so, marketing lighter and leaner products would make lamb more expensive. An important question for the industry is this: Is there a potential to generate premiums sufficient to encourage leaner lamb products?

We believe the industry will continue to market heavy lambs with carcasses weighing 65 pounds or more. The solution is for producers to produce leaner lambs at these weights. Previously cited research by Glimp and Snowder (1989), Blackburn et al. (1991) and Beermann et al. (1995) give producers and feeders production guides for lean lamb.

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Problems, Needs, Opportunities and a Prescription for the Future

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Summary

The sheep industry in the United States is something of a paradox. That the industry is in a state of decline is apparent. Sheep numbers that were near 30 million head as recently as the early 1960s have trended down to 7.937 million head on January 1, 1997. There is frustration in the industry, especially at the producer level, as to why this has occurred. Coming out of that frustration and the recent failure to vote positively on a check-off referendum, industry leaders are now asking what the future of the sheep industry can and will be. Contracts have been extended for consulting work to provide a strategic plan to restore a viable industry group presence and to provide guidelines for a return to a viable industry.

The loss of the wool deficiency payment a few years back may have been the proverbial straw that broke the camel's back for many producers. Shortly after that relatively small but stable source of revenue was eliminated by farm policy legislation, the industry saw another significant dip in total inventory numbers. Lambs generate about three-fourths of the total revenue to the sheep enterprise, but wool had been a stabilizing component of that revenue stream. The wool incentive payment appears, in an *ex post* context, to have been much more important to producers than was apparent during the time the legislation that eliminated the payment was being discussed.

This Special Issue has been designed to encompass many of the issues facing the industry. Coverage has ranged from genetics, to nutrition, to production efficiency, to overall demand, to the special sensory characteristics of lamb, to the final consumer in terms of specifics on demand and buying behavior. It is important that the product and how it is produced be considered, and it is important that high levels of efficiency in production, processing and merchandising of the product be reached and maintained. It is also important that the demand structure for the lamb product be at least stable, and problems surrounding the inability to attain that status on the demand side of the price equation have been discussed in some detail in earlier articles. Directly and indirectly, the structure of the industry has been discussed with possible implications to the economic well-being and future of the industry being attached to a highly concentrated processing and distribution sector of the industry.

The answer to viability and a positive future for the industry will not be found in any of these individual concerns. Progress will require attention to a combination of the economic forces at play in the industry. The road back to success may well require, in fact, that some of the trends and directions of economic influence be reversed. But many of these things have been known and have been discussed in prior issues. Historically, largely preoccupied with issues relating to breeding, genetics, production efficiency and quality, the *Sheep and Goat Research Journal* started to look – at least occasionally – more broadly at its industry in the 1990s. As early as the 1990 issue, Menkhaus (1990) and his colleagues looked at concentration in lamb slaughtering and its possible impact on lamb prices. This was explicit indication of a growing perception of a possible relationship between the level of concentration and prices paid to sheep producers. In 1991, the Texas Agricultural Marketing Research Center (TAMRC; 1991) was commissioned to conduct a study on marketing strategies to enhance returns to lamb producers. At about the same time, a national needs assessment survey was being conducted (by the author) at the request of American Sheep Industry Association (ASI) professional staff.

Later, Umberger dealt with management and marketing practices and how they were altered through a value-based marketing program for slaughter lambs (Umberger, 1994). By 1995, in the first issue for the year, there were articles dealing with the implications of the tariff reductions under NAFTA for the U.S. sheep industry (Peterson and Jones, 1995). The second issue of 1995 included an

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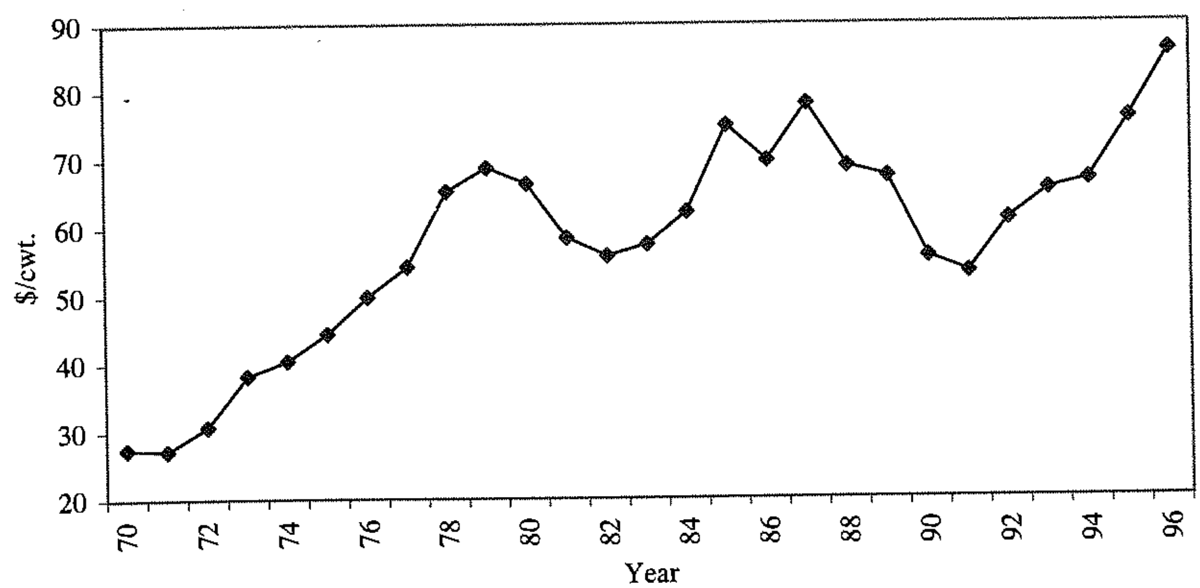
article on consumer perception of lamb compared with other meats (Ward et al., 1995). It was also in 1995, in the third issue, that the overall economic issues and the potentials in lamb marketing as keys to the future of the sheep industry were dealt with (Purcell, 1995).

It was clear that there was a new thread of thought starting to emerge by the time we moved into the 1990s. Attention started to be paid to what was happening to the sheep industry and why. The *Sheep and Goat Research Journal* started to move away from total emphasis on production, breeding, nutrition and all of the other dimensions of the production process and began to show interest in articles that dealt with marketing, markets and the demand side of the profit equation. That thread of thought and that interest grew among ASI leadership throughout the late 1980s and 1990s. Nonetheless, the total industry regressed to the point that the check-off referendum was voted down in the mid-1990s and ASI was left without operating funds except for the dollars being generated by membership fees.

A growing interest in economic viability had its roots in the periodic and sometimes sustained periods of low lamb prices. During the 1970s, 1980s and into the 1990s – until the industry downsized to the point that prices were eventually forced higher by sharp decreases in supply – producers were periodically being forced to sell lambs below cost of production. Figure 1 shows lamb prices at San Angelo, TX, in nominal dollars before any adjustment or correction for overall price inflation. If break-even prices are around $60 per hundredweight, it is clear producers were being exposed to periodic losses. Cost-price pressures persisted throughout the 1970s and yearly average prices were sometimes below $60 in the 1980s and 1990s. During those bad price years, such as 1991, daily selling prices were often far below costs. Continued cost-price pressure raises the level of angst among producers and raises the anxiety level in terms of looking to trade association leadership for answers. The USDA Economic Research Service (ERS) was charged with doing a study that examined the viability of the sheep industry. A 1990 ERS release showed that across the years, lambs in particular, and the sheep enterprise in general, had often been as profitable or more profitable than competing enterprises, but numbers were nonetheless trending lower and the industry was downsizing (Stillman, et al., 1990). Apparently, revenues were not sufficient to encourage producers to work past labor, capital, predator and market access problems and continue to persist as viable producers. As pressures continued to grow, the interest in finding solutions grew accordingly.

There is no great secret to what needs to be done when prices are periodically too low relative to costs and the economic viability of the enterprise is being placed in jeopardy. To get relief, you either have to reduce costs or you have to find a way to increase demand and enhance prices. This can become a vicious treadmill in the sense that if producers adopt technology, increase efficiency and increase output and supply with demand stagnant or declining, prices for slaughter lambs can be forced sharply lower by the increased output coming from the technologically-based supply response. Those lower prices intensify the pressures being felt from the cost-price squeeze and there is a motivation to find still more technology and still superior ways to reduce costs. *But if the selling price side never turns and the demand side never gives relief in the*

Figure 1. San Angelo, TX, lamb prices (1970 through 1996).



form of consumer willingness to pay sufficient prices, this technological treadmill becomes unbearable to some producers and they exit the industry. Once they exit, the research by Purcell and his colleagues shows that it is very unlikely and even difficult for them to re-enter if prices later look more attractive (Purcell et al., 1991). With prices in the $60s when the research was done, many producers indicated it would take a 30 to 40% increase in price to pull them back into the sheep business.

This is a phenomenon that has been seen in other sectors of agriculture including the egg side of the poultry business, beef and to some extent the dairy industry. In the dairy industry, for example, consumer reactions to products are sometimes ambivalent depending on whether you are talking about fluid milk consumption or some of the newer low-fat products like yogurt. But it is of small consolation to suggest that the lamb industry has company, and even a cursory look at the numbers suggest that the problems have been more intense and have had more of a devastating impact on lamb producers than has been the case for producers of some of the other commodities.

The intent of this last article is to trace out what needs to be done for the industry to turn back toward a viable status. There will be some barriers characteristic of the sheep industry in general that will have to be overcome, and there will have to be a significant change in attitudes of producers in their willingness to allow their professional staff and industry leaders to plan and carry out progressive programs. An approach that identifies a set of prescriptions for the future should have more benefit to all of the interested parties who are trying to move forward in this industry than a rehash of what has happened or a painful rendition of what went wrong. The better approach is to identify the problems, make brief mention of what went wrong and why and then move toward a strategic plan that has a chance to bring viability and growth back to the sheep industry. That is the objective of this article.

Key words: lamb, profitability, strategic, planning, growth.

Production Efficiency and Cost

As suggested, one source of relief from a cost-price squeeze is to increase production efficiency and reduce per-unit costs. Figure 2 shows that not many production efficiency gains were being realized in production of lamb until the 1980s. Output per ewe was actually declining in the 1970s and this phenomenon is partly associated with the breeds being used and whether the interest was in wool or lamb production. Those measures of output per ewe did improve during the 1980s and 1990s, however, suggesting that the cost-price squeeze was raising the level of motivation to adopt new technology and management practices and to accomplish some production efficiency increases. It is also the case that the low prices of the 1970s brought a restructuring to the producer sector with some producers consolidating, becoming larger and gaining economies of size.

While those gains look impressive, it is useful to compare them to what has gone on in some other sectors, such as pork, across the same time period.

Figure 2. Sheep and lamb production per ewe in January 1 inventory (1970 through 1996).

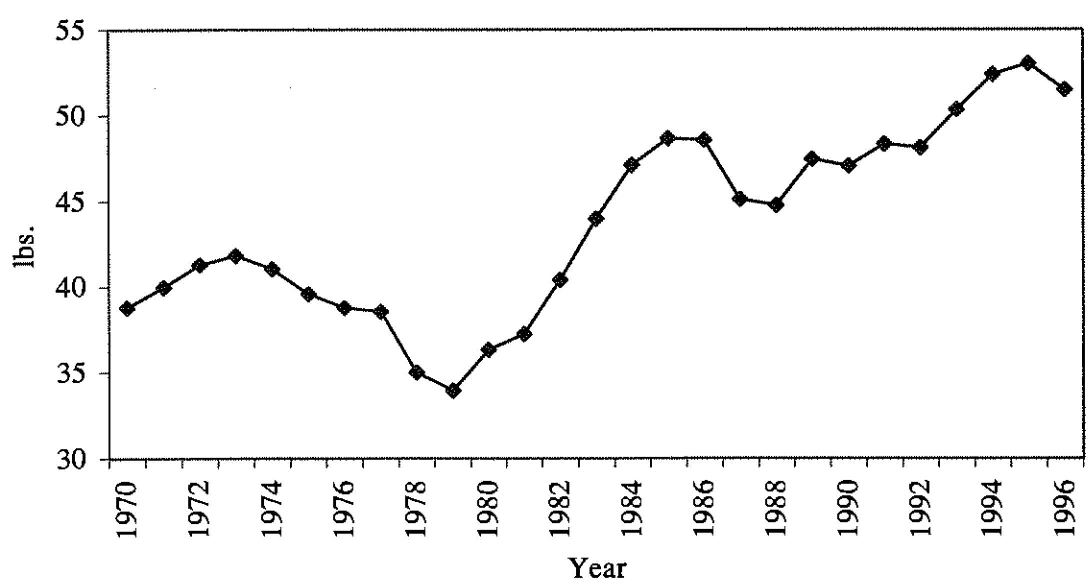


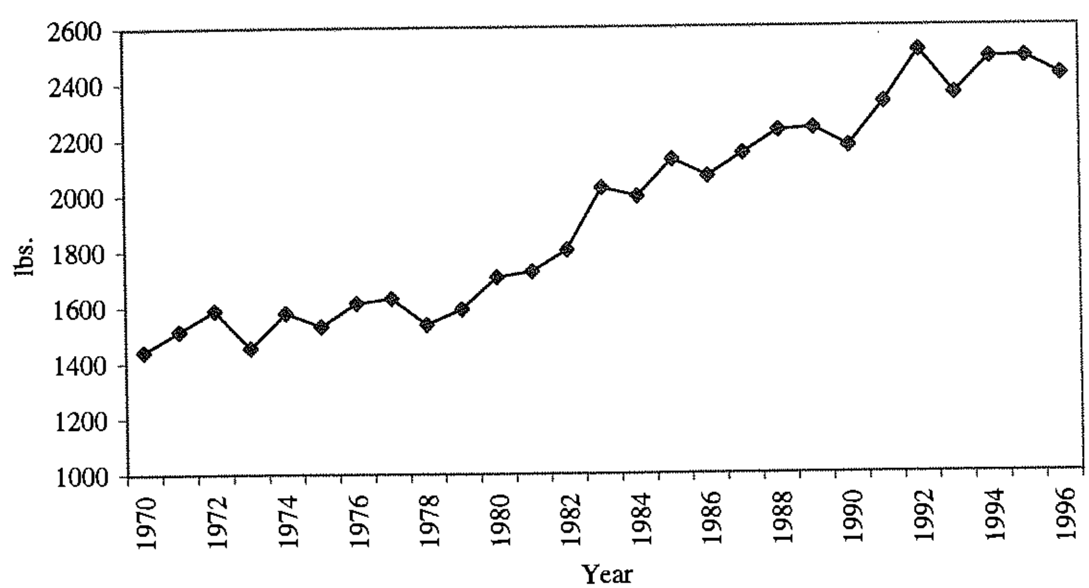
Figure 3 shows that pork production per sow was around 1,500 pounds in the 1970s and has moved up toward the 2,500 level in the 1990s – reflecting an increase of 65 to 70%. Compared to 1970s production levels of about 40 pounds, the gains in per-ewe output that have been accomplished in lamb are substantially smaller and would more nearly approximate a 25 to 30% increase in output.

It is always going to be difficult to solve or relieve the cost-price pressures by sole emphasis on reducing costs. Lambs can be a relatively expensive product to produce in terms of labor costs, predator control, specialized fencing and other inputs that tend to go up in cost over time with overall price inflation. Since there are no assurances that the selling price for lambs will go up with overall price inflation, the challenge facing the producer who wants to solve his net revenue and profit problems by only paying attention to production efficiency is of huge proportions to say the least. And we need to recall that the act of bringing in new technology to increase efficiency also increases industry supply and drives selling prices down for a given level of demand. *The industry's problems will not be solved by looking only at production efficiency and costs.*

That is not to say, of course, that production efficiency is not important. In most agricultural commodities, being efficient in the production activity is more nearly a necessary condition for economic viability and profitability over time. Certainly, the shortest path to being forced out of the industry is to be an inefficient producer with lower output per ewe, per acre or per hour of labor compared to your neighbors and compared to producers in other countries. Thus, there is no suggestion that production efficiency is not important. *What is being suggested is that it is going to be very difficult to solve the viability and profit problems of the sheep industry based totally on continued and sustained increases in production efficiency over time.*

The cost side of the equation also brings with it a totally predictable impact at the consumer level that is sometimes overlooked. If production costs on the farm and/or middlemen's costs or margins are going up over time, then the price seen by the consumer at retail will have to move up over time to keep resources in production and in processing. Without dealing just yet with whether the demand surface for lamb at the consumer level is shifting, that demand surface at any one point in time definitely has a negative slope. These phenomenon were treated in a previous article of this Special Issue (Purcell, pages 76-82) that deals with more specific demand and consumer behavior issues, but the aggregate demand surface facing the U.S. sheep industry as a producer of lamb is definitely negatively sloped. This means that at any point in time, you can move more lamb through the pipelines and into consumption only at lower prices – but the converse is also true. *If consumer-level prices are forced up over time because of a need to cover increasing costs at the producing and processing level – especially when those costs are going up because of relatively inefficient activities – then the quantity that will be taken by consumers declines.* This is a very predictable response to the law of demand, which says that at any one point in time, more quantity will be taken only at lower prices and, conversely, consumers will be willing to pay a higher price only for a smaller quantity. But the takeaway from this is that if costs are going up, which forces retail prices up over time, then the quantity taken at the consumer level declines. The percentage of the marketplace and/or consuming public that is penetrated by the relatively scarce lamb product also declines over time. Thus, we see still another reason

Figure 3. Pork production per sow, December 1 (previous year) inventory (1970 through 1996).



why low costs and efficiency in production and processing are important if your objective is to maintain an industry of a particular size or actually see it grow in terms of output and market share. But it is not just the production level where efficiency and low costs are important.

Production Efficiencies and Costs in Processing and Retailing

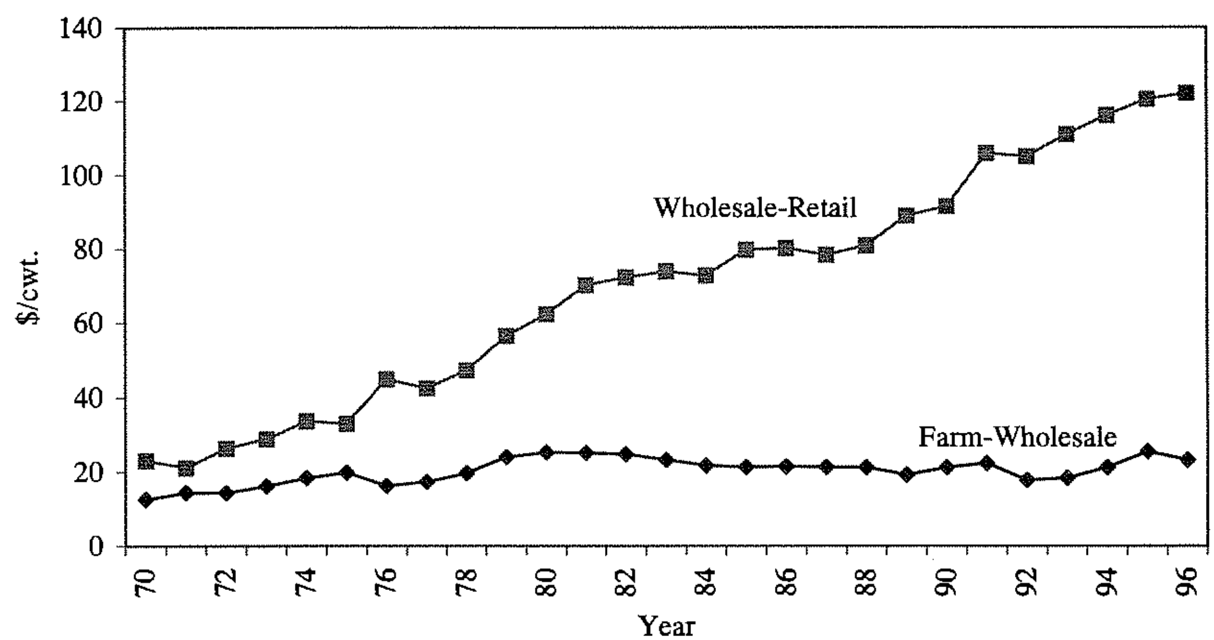
Analysis of the efficiency levels in processing and retailing are complicated by the lack of a retail price series for lambs. In other meats such as pork and beef, the USDA calculates and publishes price spread data. While those data do not give any direct measurement of profitability or costs at the packing, processing and retailing levels, they do indicate change over time. To illustrate, Figure 4 shows the farm-to-wholesale and wholesale-to-retail price spreads for beef across a number of recent years. Even a casual examination of the data suggests that the wholesale-to-retail price spread is expanding relative to the farm-to-wholesale spread and is, in turn, causing the implicit total spread from farm-to-retail to increase over time. When price spreads go up in this way, the retail price of beef or any other product is pushed up, making it less competitive at the consumer level.

Changes in those spreads do not necessarily suggest profiteering by a middleman nor do they suggest anything specifically about costs. What increases in farm-to-retail price spreads *do* suggest are that costs and/or profit margins are expanding over time, and the increases appear to be at the retail level for beef. Even these aggregate price spread data establish a base for possible inferences. Across the past 10 to 15 years when the output of the beef sector has moved almost exclusively in the form of boxed cuts as compared to hanging carcasses, it appears the margin being extracted by the retailer has increased. That is an interesting observation during a time period in which retailers are doing less to prepare the final product in terms of cutting, trimming and value-added further processing than when they were processing a hanging carcass or carcass quarters.

Not even this limited base of information and related inferences is available to the analyst in the lamb sector because of the lack of a reliable and consistent retail price series. In a 1995 look at the economics of the industry, some simplistic price ratios of various cuts of pork, beef and lamb using retail prices for lamb pulled from the industry's efforts to collect retail prices were reported (Purcell, 1995). Those comparisons suggested that if we had price spreads for lamb that were calculated with a methodology similar to those for pork and beef, they would have increased more rapidly across the past two decades than would the spreads for beef or pork. Whether those retail prices are being raised because a few cuts have to carry the value of much of the carcass or whether there is more product loss in lamb than in the competing meats is not known. Thus, one should not draw any hard and specific conclusions from the data, but even a limited ability to look and examine suggests the presence of something less than efficient and progressive activities at the processing and retailing levels in lamb.

Menkhaus and his colleagues looked at whether or not a lamb-processing sector that was increasingly concentrated would cause producers' prices

Figure 4. Farm-to-wholesale and wholesale-to-retail price spreads for beef (1970 through 1996).



for lambs to go down (Menkhaus et al., 1990). Because of data limitations, the authors reported that they couldn't draw any strictly definitive conclusions, but they did find some evidence to support an inference that when there is only one buyer in a region, prices for lambs would be substantially lower. It appeared that if there were at least two and possibly as many as five buyers, prices were essentially the same as they would be with more numerous buyers. This finding suggested that concentration, where the marketplace still involved at least two or more large firms, was not a huge factor in limiting or constraining lamb prices over time.

One of the performance measures that federal regulators like the Justice Department, Federal Trade Commission or Packers and Stockyards Administration and policymakers have always watched in a concentrated industry is progressiveness. Researchers who have analyzed the relationship between measures of structure (i.e., concentration) and performance (i.e., price level, size and behavior of margins) and other measures of industry-level performance have talked about progressiveness. Basically, being "progressive" suggests an aggressive posture with regard to investments in research and development to develop new products and markets and to adopt new technology to keep the industry viable and growing. Even the limited database that can be generated for the lamb sector would suggest that there is a lack of progressiveness at the processing and retailing levels. It is very difficult to find evidence of investments in new products or new markets or in new ways to merchandise a product coming from the highly concentrated processing industry and/or from a retail sector where the attention paid to the lamb offering is often minimal and is often only responsive to demands or requests from a minority of the retailer's customers.

It is important that every effort be made to improve efficiency and reduce cost of producing, processing and merchandising the lamb product. There is clearly progress that could be made. Any reduction in costs of providing the services from the point of original production to the final consumer will allow the product to be offered at the consumer level at a lower price. That makes lamb, which is often priced above some of the competing meats, more competitive at the consumer level. Thus, anything that can be done to increase industry-wide efficiency, which will have to start at the individual producer and/or processing firm level, will clearly contribute to long-term economic viability of the sector. But as already suggested, it will be very difficult to restore industry viability emphasizing only production efficiency and costs.

The Demand Side of the Profit Equation

There are two important components to the profit picture for any agricultural commodity and lamb is certainly no exception. Profits can be generated and/or maintained over time by the ability to reduce costs for a given price level and keep the operation viable. Even when prices are coming down, it is possible to be profitable if the costs can be reduced sufficiently to offset the negative impact of decreasing selling prices.

The previous section indicated that while progress has been made in increased efficiency in lamb production and processing, the picture is not one of overwhelming success. The increase in output per ewe across the past two decades would, at best, no more than offset the tendencies for the costs of inputs such as labor, machinery, fencing and capital to go up over time with overall price inflation. If that is a fair assessment of what has been happening on the production efficiency and cost side, then we have to turn to the other side of the profit equation to look for answers as to why the industry has downsized in such a dramatic way. If we find that in addition to difficulties in continuing to drive production and processing costs down that selling prices have tended to decline, then the nature of the problems associated with the cost-price squeeze becomes more apparent.

Analyzing the demand situation for lamb in even a descriptive capacity is made difficult because of the absence of any price series at retail since the early 1980s. The USDA stopped collecting and disseminating retail lamb prices under the weight of budget cuts and the series has never been restored. Thus, it is difficult to look at something as simple as a price-quantity scatter plot, the type of approach that is relatively easy and also very instructive in other meats such as beef, pork and poultry.

A proxy for a demand scatter plot can be generated by plotting commercial production against inflation-adjusted lamb prices. Those plots have been used in earlier efforts (such as the previously cited article that looked at what is happening on the demand side; Purcell, 1995). The plot updated and repeated here in Figure 5, for purposes of exposition, is a scatter plot of inflation-adjusted prices against commercial production of lamb and mutton since 1970 with the years through 1996 identified in the diagram. These are live lamb prices and are not, of course, prices that the consumer sees directly, and margins at the processing and retail levels have apparently increased over time. Those margin increases push consumer-level prices up, reduce quantity taken by buyers and may force supply reductions at the producer level via lower derived prices.

What we have, then, is only a proxy for a demand "surface," but it is nonetheless very revealing. The picture painted by the plot is not encouraging and suggests the source of much of the pressure that has forced investments out of lamb production and brought the significant downsizing in the industry.

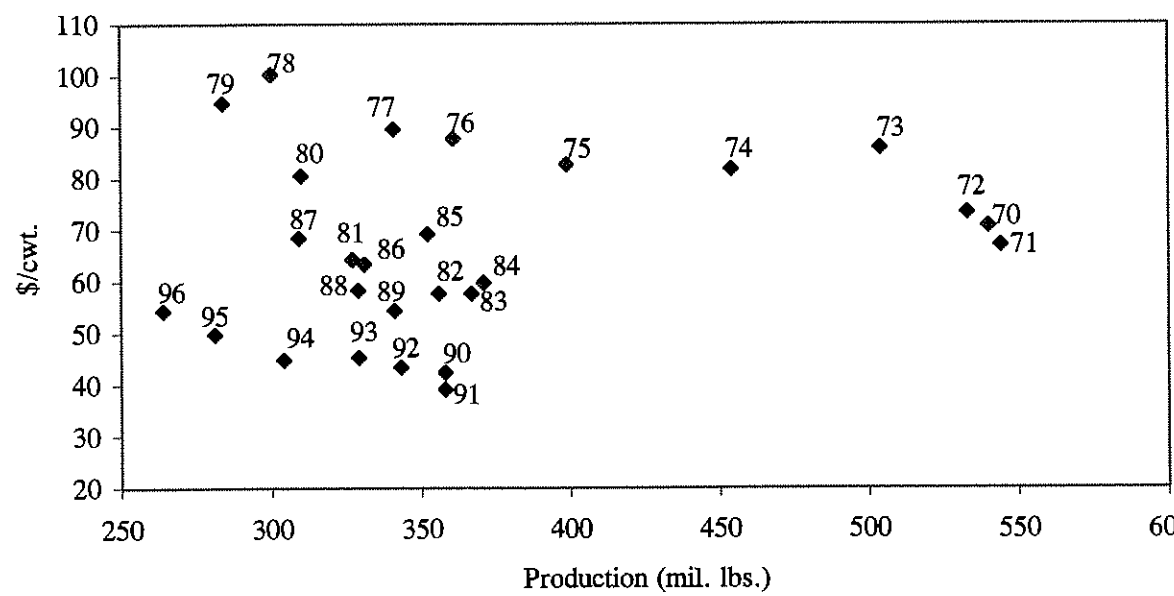
As suggested earlier in this article, any demand surface along which price and quantity relationships are being traced out slopes down and to the right. For purposes of illustration, it is useful to think about a negatively sloping line of about 45° being superimposed on the scatter plot in Figure 5. Mentally sketch a negatively sloping line through the mid-1970s coordinates such as 1975 and 1976. Then, repeat that same exercise and pass one through 1985 or 1986, and then continue down and to the left and pass a negatively sloping line through the more recent years of 1995 and 1996. We are taking some liberty with the analytics of this situation if we keep those lines roughly parallel, but just this simple approach starts to demonstrate the nature and the magnitude of the problem. Looking at a particular quantity being produced and offered and at the roughly 340 million pounds produced and sold in 1977 as compared to essentially the same amount in 1992, we see that the price in constant dollars is in the $40s for the 1992 demand surface and in the high $80s for the 1977 demand surface. Eliminating the impact of overall price inflation converts all the prices to constant 1982-to-1984 dollars, provides a "common denominator" and allows legitimate price comparisons between and across years. The prices for 1977 and 1992 used for this illustration are not being distorted by price inflation and they reflect the true underlying supply-demand dynamics. *It is apparent that 1992 was on a far lower demand surface than was 1977.*

It is instructive to reflect on what is happening in the industry as captured by this simple scatter plot. Generally, the coordinates that show production levels and the prices at which they are moving in terms of inflation-adjusted prices at the producer level have been moving down and to the left over time. *That pattern suggests a long-term consistent and persistent move toward a decreased demand surface that started, perhaps, around 1980 and has continued through 1996.*

As noted, the prices have to be adjusted for inflation to allow us to focus on what is happening in the underlying supply and demand dynamics. If this plot allowed lamb prices to be influenced upward over time just because of overall price inflation, it would look somewhat different. The 1996 prices, instead of being in the mid-$50s, would be closer to $80, but those comparisons are not legitimate. Our need is to find out what is happening to the demand surface over time *behind the complicating influence of overall price inflation.* It is also useful to reflect on the fact that if we had legitimate and accurate per capita consumption data and retail prices, this would also influence the pattern we are plotting. If those commercial production numbers on the horizontal axis could be converted to per capita consumption data, *we would see the move to the left of the demand surface be accentuated because per capita consumption is falling more rapidly over time than is the total level of production.*

Figure 6 shows these data in a somewhat different way, and sometimes this approach is more intuitive for those who are trying to decipher what is going on in the industry but are not accustomed to the analysis of demand. Shown are the same production and price data that are reflected on the scatter plot in Figure 5, but they are converted to line plots over time. Notice that in the 1970s the typical inverse relationship that we would expect was readily apparent. As production came down significantly during the decade, price for slaughter lambs in San Angelo, TX, in constant dollars, increased substantially. *That is the type of inverse price/quantity relationship we would expect if, behind the scenes, those quantity and price data were interacting along a constant demand surface.* Reference to Figure 5 suggests that we were on something approaching a more nearly constant demand surface during the 1970s although the drift to the left was starting to be apparent and was picking up momentum late in the decade. Turning back to the line plots in Figure 6, note that during the

Figure 5. Commercial production of lamb/mutton and inflation-adjusted prices (CPI, 1982-to-1984 = 100; 1970 through 1996).



1980s and 1990s, the inverse relationship between production and price continued to be present. The surge in production in the 1983-to-1984 period pushed the inflation-adjusted lamb prices to $60 and below. Then, even the modest production or supply surge that occurred in 1990 and 1991 pushed inflation-adjusted lamb prices all the way down to the $40 level. *This clearly suggests that the 1980s and 1990s were witnessing a move to a lower demand surface or an overall weaker demand for lamb.* That is reflected intuitively when you note that lower levels of production in the early 1990s generated prices substantially below the price lows of the early 1980s. Such a development is going to occur only when the demand surface is shifting down and to the left and pulling the price lower for whatever quantity happens to be offered by the industry in any particular year.

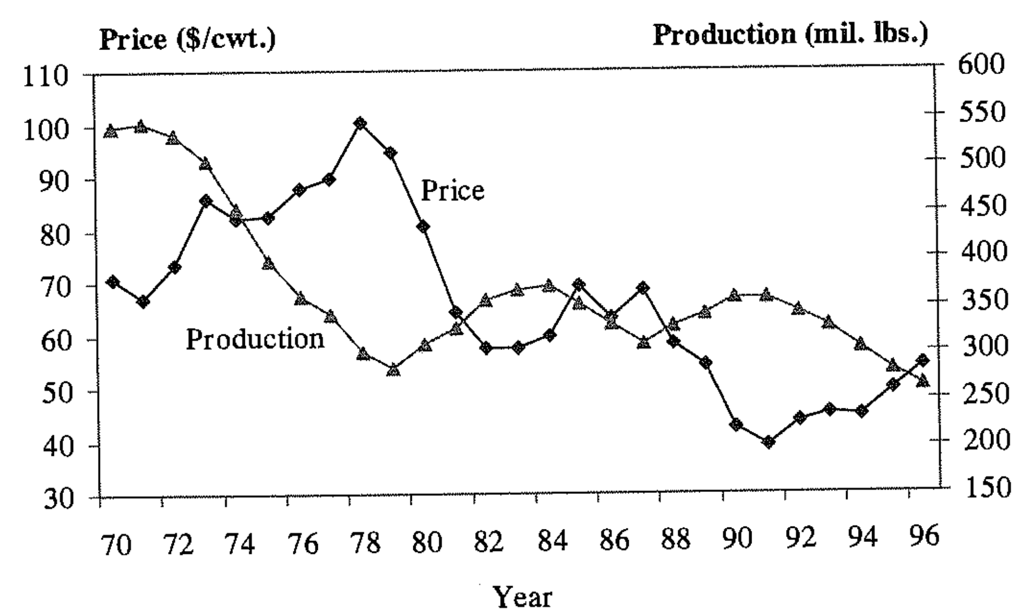
Figure 6 shows the resurgence in inflation-adjusted prices for lambs in 1995 and 1996. Figure 1 showed nominal prices pushing up toward $90 in 1996. The inflation-adjusted price of roughly $56 per hundredweight for 1996 in Figures 5 and 6 would need to be multiplied by a Consumer Price Index factor of approximately 1.57 to re-inflate the prices, and that would push the $56 price up to the high $80s for the year as suggested in Figure 1. But examination of both of the plots being discussed in this section makes it clear why the higher prices of recent years were present. *Those higher prices were coming in response to the sharp decreases in production in 1995 and 1996.* This is testimony to the simple economic fact that you can generate higher prices if you reduce the supply sharply, even if demand is declining.

It seems clear that we must add the demand side of the price equation to the production and supply side as a factor in what is going on in the industry. Indeed, it appears that the long-range economic pressure that is driving the industry to a smaller status and forcing disinvestment on a widespread basis at the producer level is coming from the demand side. That suggests, in turn, that any look at strategic planning for the future has to consider what is happening on the demand side of the equation, what might be done to improve the situation and must include an assessment of how important this particular issue is to the future well-being of the industry.

Investments, Disinvestments and Incentives

The sheep industry is obviously much smaller than it was historically. There has been a long period of forced disinvestment with much of the pressure apparently coming from long-run weakness in demand for the final product. Increased efficiency at the producer level has helped, but limited evidence suggests that efficiency has not increased in a parallel fashion at the middleman level. There is a basic

Figure 6. Commercial production of lamb/mutton and inflation-adjusted prices (CPI, 1982-to-1984 = 100; 1970 through 1996).



truism to all of this: There is only one source of economic incentive (money) to reverse long-standing trends and change the sheep industry to a growth industry again. That source of incentive is the consumer's food dollar.

All of the economic functions from the seed-stock producer, through the commercial producer, to the lamb feeder, to the slaughtering facility, through the breaking function, through any wholesale or brokering activities that are involved, and to the retailer have to be financed by what the consumer pays for the final product offering. *If that product offering is found wanting in some significant way, consumers will take the product only at relatively low prices.* The result of this phenomenon is clearly documented in the previous analysis. Price pressure is extended down toward the producer level, and if sufficient increases in efficiency cannot be garnered to make large reductions in production costs, the marketplace is in the process of running resources – including producers – out of the industry.

If the demand-side pressures cannot be offset by increased efficiency and reduced costs, then an obvious and complementary strategic alternative is to improve demand. Strength in demand takes pressure off the need to grab technology and get more cost effective, and is the source of financing for new investments in production of any food commodity. Increases in demand manifest themselves in the form of a consumer's willingness to pay higher prices for a given quantity of product or, even more effectively, pay a higher price for an increased quantity of product.

The importance of this is apparent. If consumers will pay a higher price for an increased quantity of product, especially a higher inflation-adjusted price, *then there can be sufficient monies available to encourage and finance the investments needed to expand production.* This type of pattern is characteristic of a growth industry and is especially characteristic of an industry that is growing because of "demand pull" as contrasted to "cost push" growth based on increased production efficiency and reduced costs. When both are occurring, of course, the situation is exceptionally powerful. Both cost reducing technology and increased demand for the final product offering have fueled growth in the poultry industry, throughout the decade of the 1980s and into the late 1990s. But examination of what is happening in the sheep and lamb sector clearly indicate that it is not a growth industry. Inventory numbers are below historical levels and production has plummeted in recent years. Thus, it is apparent that some basic trends need to be reversed if growth is to come back to this industry.

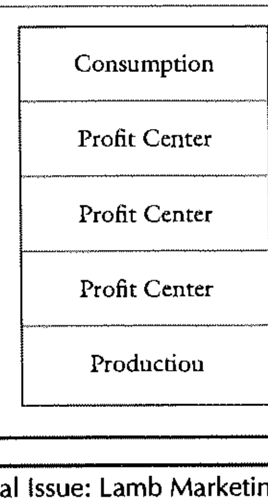
In previous sections, there was considerable discussion indicating that efforts to reduce cost and stimulate growth in that fashion have not been sufficient. The demand-side difficulties have been dramatic and have more than offset what the producer has been able to do in terms of increased efficiency, especially in the presence of performance at the middleman level which does not appear to be impressive. There is little doubt, then, that the primary basis for growth in the sheep industry has to come from the demand side. *If demand is to stimulate new investments and restore a pattern of growth characterized by increased commercial production and increased per capita offerings and market share, then the consumer has to be willing to pay higher prices for the product offering at the consumer level.*

The issue of demand and what will be required to reverse the recent negative trends has to be at the top of the priority list. Surveys and analyses of what is occurring at the consumer level indicate that both market development and product development are needed (Purcell, 1993). The two are complementary. The product offering needs to be moved toward the preferences of a modern consumer who is much less inclined to spend time in food preparation and is much less knowledgeable about how to prepare food than was the previous generation. As that product offering is changed, it needs to be changed consistent with the socioeconomic profile of the typical consumer in a particular market area, so market development and targeting to market segments emerge as complementary needs. It is a tautology to suggest that if consumers are going to pay higher prices for lamb products and finance an expanded industry effort, then their attitude toward the product has to be changed as compared to the attitudes that have prevailed during the 1980-to-1997 time period.

For expository purposes, then, it is useful to assume that investments in market development and product development will be needed. The question then becomes the source of such investments. More specifically, what participant in the production-marketing chain or continuum that reaches from the original producer to the consumer has an incentive to make the investment needed to do the research work in market development and product development? In the form of a related question, if the need has been present, why hasn't that need been met? Why is it that consumer acceptability as evidenced by willingness to pay for even a reduced level of product offering in recent years appears negative at best? Why hasn't that situation been corrected? The essence of this issue revolves around whether there is an incentive for any particular player in the system to make the investment; and if not, why are those incentives not present?

Figure 7 offers a useful point of departure for discussion. It is a simple

Figure 7. Illustration of multiple profit centers between lamb producers and the consumer.



schematic that shows the possibility of several profit centers between the original producer and the final consumer. How many profit centers are present is not of paramount importance here. What is being suggested is that each level of economic activity, as the product moves up through the system and is prepared for the final consumer, is owned by and controlled by a separate economic entity – a separate profit center. What we have, then, is a system with three to four profit centers between the producer and the final consumer – each of which has goals, objectives and some sort of strategic plan as to what it wants to accomplish. *It is imperative that it be recognized that a combining of goals, objectives, economic plans and related activities from separate and independent-thinking profit centers does not necessarily generate an effective agenda for the industry.*

Put another way, it is useful to think about the production and marketing system that is being discussed here within the confines of a single firm. Each of the various levels of activity that are now being performed by a separate profit center would then become a function under the auspices of a single management, a single profit center. If you were managing that firm, what would you do to ensure its viability and growth over time? Almost everyone would provide answers that deal with the need to coordinate those various functions within the confines of that firm so that the final product offering would be acceptable and desired by the consumer and that the overall operation – not any one of the functions within it – would be profitable, viable, proactive and forward-looking. That reasoning is obvious, it is apparent and it cannot be criticized. But if you look at what is going on in the sheep industry of 1997, the problems facing the industry become immediately apparent.

There is no magical guiding hand in the lamb sector to ensure that what is produced will be processed and passed through a value-added further processing series of activities and made available at the consumer level in line with preferences and willingness to pay dimensions of the modern consumer. Theoretically, all of these activities in a system characterized by separate ownership at the different levels of activity are coordinated by the price mechanism. The consumer votes "yes" or "no" on a particular product offering. When an answer is "no," the system determines why that offering is not satisfactory and generates a signal down through the system to the producer as to how they need to change. Obviously, any such price signal has a tortuous path to run in the industry as it is currently configured with often-adversarial relationships between the producer, the lamb feeder, the packer, the retailer and several other intermediate operations within the system. *The pricing mechanism has failed in prompting the type of coordination that is needed to ensure that what is produced is consistent with what the consumer wants and will pay for.*

Having argued that the pricing mechanism has failed, it is useful to step over into sister industry sectors and monitor what is occurring there. In the overall battle for market share in the meat sector, poultry has long understood the need to cater to the particular consumers' whims and make sure that whatever they want gets offered. Most of the poultry industry is vertically integrated, which means there is no separate profit center running the feeding floor and no separate profit center at the slaughtering level. Rather, the integrator controls everything from the decision on genetics to how the package is wrapped and presented to the customer. All of the program is oriented toward serving consumers who know what they want as lifestyles change and as the demands for consistent high-quality and easy-to-prepare products start to dominate buying decisions.

In pork, much of the new capacity coming into pork production across the past 10 years has been in the hands of large producers or is under the control of large processors. A number of the new players in pork have moved into pork slaughtering and processing from the poultry sector and brought their merchandising knowledge with them. A significant percentage of hogs now being produced in the U.S. is produced under circumstances where non-price means of coordination are important. Packers control decisions on genetics in production facilities that they own and they have extended control of genetics, rations and management regimes into contract production programs. The apparent incentive is the opportunity that is being seen at the consumer level if the product offering can be made more uniform in terms of quality and moved toward the modern consumer's preference patterns. *The important thing to recognize is that in pork, without getting into the pros and cons of moving away from heavy reliance on the independent producer, the investments in market and product development are being made.* Non-price means of coordination are slowly but persistently replacing the price mechanism and, for a substantial part of the industry, the profit center syndrome and all the problems it entails are being eliminated.

There is arguably a useful message here. After many attempts to establish a value-based pricing system in hogs, the key players in the pork industry are now moving away from reliance on the price mechanism and toward non-price means of coordination. Coordination is by management directive rather than price, and no single economic function has to be profitable. The objective is to generate profits from the combined production, processing and distribution activities, and in that sense, part of the pork sector is moving toward the type of control and coordination that has long been present in poultry. Future growth in pork is likely to continue to come in the form of relatively large operators who are combining two or more levels within the system and are *forcing* the needed coordination that the open-market price system has not provided.

In cattle, the situation closely parallels that in sheep. There are several separate profit centers between the cow-calf level of activity where decisions on breeding and genetics are made and the final consumer of the beef product. Beef was hit extremely hard by decreases in demand and demand-side problems that started in the late 1970s and have persisted through 1997. The industry had reached 132 million head of total cattle and calves in 1975 and then dipped toward 95 million head near 1990. Disinvestment was rampant in the late 1970s and through much of the 1980s with the rough equivalent of 300,000 average size beef cow-calf operators being forced out of the business as the beef cow herd fell from 45.7 million head in 1975 down to 33.1 million head in 1989, a 12.6 million head (27.6%) reduction. In beef, unlike the situation in pork, the important investments in market and product development are not yet apparent.

There is apparently no single player in the production-marketing system in beef that feels they can make and sustain the large research and development investments that would appear to be needed. That may be because no single player can see how they might capture the benefits. It is a different class of livestock and a different setting than that which prevails in pork, and certainly different than the one that prevails in poultry. Integrating the various activities and the various functions is difficult even if anyone sees that approach as desirable. A large percentage of the beef cows in the U.S. continue to be in the hands of very small operators with fewer than 50 cows, and these are usually part-time operators who may or may not be greatly concerned about genetics and breeding decisions. Again, the parallel with sheep is interesting. Much the same situation prevails in the sheep sector where part of the breeding herd is in the hands of small operators, many of whom are part-time operators and who earn much of their living off the farm.

It would appear, then, that the sheep sector is going to have difficulty finding some player in the current system with the incentive to make the substantial investments to do the market and product development work needed to turn some of the negative trends around. If this is true, then the needed investments are going to be slow in coming or will not be made at all. If this is a correct assessment of the situation in sheep (and history and its lack of action suggest that it is correct), then some other source of incentives for market and product development has to be found. *It puts a premium on the restoration and use of check-off funds to finance product and market development research, and it places a premium on having leadership for trade groups at both the state and national level find ways to change what is being produced and offered.* From this viewpoint, it is useful to examine what we know and what has been done in the broad area of lamb marketing, the related areas of understanding the consumer, the strengths and weaknesses in the demand for lamb and assess what will be needed in the future in terms of strategic programs to move the sheep industry back toward a growth industry again.

Lamb Marketing, Pricing and Pricing Signals

Overall, when the concept of a marketing system is being discussed, reference is typically to a production-marketing continuum that is characterized by separate and independent ownership at the various levels in the system. This type of system, as noted above, has several profit centers between the producer and the final consumer. In such an open exchange system featuring separate profit centers, it is the pricing mechanism that is typically looked to as an allocative mechanism and as a mechanism to coordinate economic activity. This concern was discussed earlier in the article, but we need to look at it in more detail.

The allocative function is important but may be of less interest to us here. It deals with the notion that monies and investments tend to go to those areas where economic opportunities or profit potentials look the best. Profits, in turn, are related to the price at which the final product can be sold. Over time, we have seen investments move into the poultry sector and move out of the traditional "red meat" sector (beef, pork, lamb) as buying behavior and preference patterns changed at the consumer level. This is an indication of the pricing mechanism performing an allocative function as it directed the reallocation of investments over time by showing different price trends for poultry versus the other meats.

The coordinating charge to the pricing mechanism inherent in the open marketing system is of much greater interest here. The basic idea, recall, is that price signals reflect the wishes of consumers back down through the system and prompt needed changes in what is produced, when it is offered, etc., at the producer level. Entire textbooks have been written about these open-market pricing systems and what they are supposed to do. With each of the profit centers involved along the continuum between the producer and the consumer pursuing a profit maximizing motive, the idea is that price signals will be transmitted through the system to accomplish an effective coordination between what is produced and what is in demand at the consumer level. The extent to which such coordination is achieved is a measure of the level of vertical coordination that is achieved and will be an important determinant of the efficiency of the system. An efficient "system" is not unlike an efficient firm in that each of several technically-related functions work well together and are effectively coordinated. Even if we assume the price signals are effective, research shows long (several weeks or even months) time lags before retail prices, for example, respond to changes at the producer level (Jones and Purcell, 1993). Add the complications associated with the time lags to the fact that grade descriptors used in pricing do not identify all of the value-related product attributes important to the consumer, and it is easy to see why the price-based system has failed.

Non-price means of achieving the needed coordination are starting to be commonplace. Coordination of the vertically-related stages of economic activity can be accomplished by several non-price methods. The most apparent, and arguably the most effective, involves vertical integration where two or more of the economic stages of activity are brought under the same ownership and under the same management control. This happened many years past in the poultry sector and is starting to come into the pork sector as some large packer/processors integrate downward into producing their own hogs, controlling the genetics, reducing the level of product variability, etc. Another way to accomplish essentially the same thing is through tight contractual relationships where a processor contracts for production of livestock of a certain specification. In broilers, this has meant the contractor controls most of the important decisions on genetics, rations, medications, etc. The contracts that are starting to emerge in the pork sector are similar in that the producer becomes the overseer of the program, but decisions on genetics, rations and the overall management regime are made by the contractor. *Whether it is vertical integration or vertical coordination by contract, these are clearly non-price alternatives to the price mechanism as a means of achieving coordination between the various levels of economic activity and ensuring activities are consumer driven.*

There are obvious philosophical and policy issues surrounding the moves away from an open price exchange system toward controlled systems either by ownership or by contract. Questions arise immediately as to the role and the viability of the independent producer in a system that is moving away from price and negotiated transactions as a means of coordination. While not diminishing the importance of those policy-related issues in any way, the discussion here will focus on why there will tend to be moves away from reliance on the pricing mechanism in lambs or in any other class of livestock over time. Alternatively and indirectly, the discussion will reflect what is required for a system characterized by separate profit centers and open-market negotiated prices that do not accomplish pricing to value to be effective as a coordinating mechanism. Implicit in the discussion is the notion that *if the pricing mechanism is not effective, it will tend – inevitably – to be replaced by non-price means of coordination.*

It is useful to recognize that this is not a new idea. Agricultural economists in the 1950s, 1960s and 1970s were discussing this issue and pointing to the importance of achieving high levels of coordination along that "assembly line" between the producer and the consumer if the price-based systems were to survive (Purcell, 1973). In the late 1990s, it is becoming abundantly clear throughout agriculture, and especially in the livestock systems, that the pricing mechanisms have not been sufficiently effective to deter moves to non-price means of coordination.

Internal to the price discovery process is the issue of *pricing accuracy*. Basically, this refers to the idea that the price attached to a particular product offering should be consistent with its true value based on final use. This is, of course, why grades are so important in the pricing of agricultural products. In the livestock sector, there has long been a tendency to grade livestock in terms of a quality grade and, in more recent years, in terms of what is called a yield grade (YG), a measure of lean yield to total carcass weight.

At the retail level where the consumer examines the product offering, it has been clear for at least 15 years that the consumer does not want to buy a product covered by an excessive layer of fat. That same consumer would also prefer not to buy a cut of meat that is characterized by seam fat or other indicators of waste – they do not want to even *see* the fat, even if it can be trimmed off and discarded. These preferences have developed in an era in which there has been increased emphasis on nutrition and on what is consumed. The modern consumer is looking for a product consistent with norms as to what should be consumed in terms of not just caloric count but also fat content, cholesterol, etc. Beyond that, it is also becoming increasingly clear that they want the product to be convenient to prepare.

In recent years, there is a move toward yield grading every slaughter lamb that is quality graded. Quality grading and yield grading have been "coupled." What this means, presumably, is that a Choice YG-2 lamb weighing 135 pounds is of higher value than a Choice YG-4 lamb weighing 135 pounds. The YG-2 lamb will cut out a higher number of pounds in terms of lean retail-ready cuts than will the YG-4 animal and price to the producer should, therefore, be higher for the YG-2 animal. In practice, the industry has tended to price the live animal based on quality grade, usually insisting that the lamb either be Choice or Prime, and on the dressing percentage of the lamb. This means that emphasis is placed on a lamb that dresses 54% of liveweight in terms of a carcass weight as compared to a lamb that dresses, say, 51% of liveweight. The lamb dressing 54% of liveweight has tended to command a higher price than the lower dressing lamb.

The problem with this pricing base is that there tends to be higher deposits of external fat and other indicators that move the lamb into the poor yield grade categories, such as a YG-4 or YG-5, when the dressing percentage goes up. There can be exceptions, and this points to the importance of genetics, breeding and management during the feeding phase. But the general tendency for yield grade to deteriorate when dressing percentage goes up has been widely observed. In addition, the recent move toward requiring yield grades carried with it an attempt to streamline the process and make it easier for lambs to be yield graded along the high-speed lines in the modern packing plants. The new formula uses only back-fat thickness and drops the use of leg score and kidney/heart fat that were included in the earlier voluntary yield grading program. Analyses suggest that the yield grades are much less reliable when only a single indicator back-fat thickness is used and this adds an additional element of uncertainty, variability and lack of precision to the pricing process (Purcell, unpublished research).

The important point dealing with pricing accuracy is that there must be a means of segmenting the value variation based on final end-use considerations in a product offering. Whether it is grades or some more detailed specification process, it is impossible to value a product attribute in the pricing process that is not identified and brought into the negotiation of that price. It is a tautology, then, to suggest that price discovery can be effective only if there are high levels of pricing accuracy and that the pricing efficiency of the system is predicated on the level of pricing accuracy.

In lamb, there are still apparent problems. The now-linked quality grade and yield grading mechanisms are not being widely used. Where they are used, there is no clear indication that the YG-2 lambs are consistently commanding a premium. What often happens is that the price discrimination is one-sided in nature. The YG-4s and YG-5s may be discounted compared to a YG-2 or a YG-3, but no premium is paid for the YG-2s. This effectively negates the capacity of the system to achieve a high level of pricing accuracy and to thereby meet a necessary condition for effective price discovery and a high level of pricing efficiency. And in the process, it generates a powerful motive to move to non-price means of coordination because the levels of vertical coordination achieved by the pricing mechanism in an open-market setting are not high.

The open-market and price-based exchange system characterized by separate profit centers that perform the various economic functions between the producer and the final consumer of lamb has failed in its assigned task of achieving coordination between what is produced and offered and what the modern consumer wants. Pricing processes are imprecise, product descriptions such as yield grades that have the potential to identify value-related attributes are not being widely used in price discovery, the level of pricing accuracy being achieved is low and the time required to transmit any price signals appears to be excessive relative to the other meats (Jones and Purcell, 1993). The result is a system that has trouble coping with seasonal changes in slaughter levels, and the marketing pipelines are "clogged" by seasonal increases in production in the face of retail prices that are slow to respond to encourage increased movement into consumption. The bases for pricing live lamb are inconsistent with needs in an era in which consumers are looking for lean products. *Perhaps most importantly, there is no single participant in the system as it is now configured who is willing to make the investments in market and product development that will be needed to revitalize the product offering and move it toward the desires of the modern consumer.* Without that investment in improved marketing and merchandising, the lamb sector is destined to continue the negative patterns of loss of market share, forced disinvestment and downsizing of the industry. The lamb "marketing system" will continue to fail.

Toward a Strategic Plan for the Future

The primary need to move the lamb sector back toward profitability and viability is not, given what we have examined, mysterious nor is it difficult to see and identify. *The consumer has not been willing to pay a price sufficient to keep resources coming into the industry.* Rather, the pattern has been in the other direction. Prices on even a reduced quantity of product have often been significantly lower in inflation-adjusted terms at the producer level. Resources are being forced out of the industry. This all argues that something is wrong with the offering and/or with the effectiveness of the system between the producer and the consumer such that the modern consumer's needs are not being met.

It is imperative that the product offering be modernized and changed. In the prior section, it was suggested at some length that the open-market pricing system is not going to accomplish that need. Pricing accuracy is faulty at best, the price discovery process has failed to price to value and there is no assurance that what is produced at the farm level provides a lamb that establishes a product base from which the preferences of modern consumers can be met. In the face of those difficult and negative conclusions, some other approach has to be employed.

It is time to look at vertical alliances in the sheep industry. It is time also to appreciate and understand that many of the professional staff in ASI, as it was configured before the negative vote on the check-off, had recognized this need for years. The programs and the moves toward modernizing the product offering that were discussed in seminars and in annual meetings of ASI were never put effectively in place. With all due respect to the efforts made by the Lamb Council, which was responsible for advertising and marketing the lamb product, not many of the truly significant needed changes were ever accomplished. In too many market areas the offering is still a lamb chop that is priced relatively high and appears on vertical inspection to be 30 to 40% fat. The other offering may be a whole leg of lamb or a half leg of lamb, neither of which many of the modern consumers know how to prepare. The success that has been enjoyed on movement of lamb into consumption has been primarily in specific market areas where ethnic groups or particular sectors of the populous have not only understood how to prepare the product but for various reasons have wanted the lamb product and have bought and consumed it consistently – even if they have to seek it out.

But those niche market successes, although important, have not provided the base of consumer dollars that is needed to restore viability to the industry. That sufficient base is only going to occur when a product offering is presented to modern consumers that fits their desires for a consistent high-quality eating experience, a product that is perceived to be low in fat and/or cholesterol and a product that is relatively easy to prepare in a society where the vast majority of the meals are now prepared in the microwave. *It is only when that type of product offering is made available on a broader basis to the modern consuming public that we will have met the necessary condition for the sheep industry to turn and move in a positive direction.*

Under the assumption that some new industry trade group association will evolve, it is imperative that producers who have a vested interest in all this allow their paid professional staff to function. Ideas that have been generated in past years that would have made at least modest improvements in the product offering died in the committees and councils dominated by producers who have never been totally willing to accept that their product has a problem at the consumer level and who have never been willing to help finance progressive programs that would solve the problem. The elected leaders – the producers themselves – did not understand the need or could not get their own more progressive and forward-looking programs approved by the councils and committees. In the modern industry, it appears that those types of changes are more likely to get made within an alliance of producers, processors and retailers as nurtured and coordinated by a professional staff than in a failed open-market pricing system that shows no evidence of moving to a functional status.

Improvements from both sides of the profit equation are needed and, indeed, may be available within the confines of an alliance system. *There are significant efficiencies to be gained by coordinating the various levels of economic activity in the lamb-production marketing system much like they would be coordinated if they were under the management control of a single manager or single management center.* Those who are managing the alliance will be able to ensure that producers get paid in accordance with value of their lambs in a final-use context because they can generate accounting measures, assuming identification of animals can be maintained, to produce those value measures. That information will focus producers' efforts and make them more efficient. There is widespread anecdotal and research evidence to suggest that it is extremely important to keep a steady flow of lambs into any processing facility (Purcell, 1992). If the alliance-owned (or alliance-contracted) plant can operate at or near its designed capacity, that keeps costs down and those increased efficiencies and reduced costs can be shared by alliance participants. Those increased efficiencies may be enough to finance the alliance once it is started. But as important as these gains may be, they are not the source of the biggest potential gains. *The key is that the alliance will have an opportunity to identify a market segment and focus product offerings on and toward the needs and preferences of that market segment.*

By focusing the product offering, there is a very real and significant potential to increase the value of the product and to tap into a consumer's willingness to pay for quality, consistency and convenience. Prices to the consumer may actually increase, but they will not be seen as "high" if high levels of value are seen in the product offering and the value-added dimensions it offers. This type of arrangement will allow the same type of reaction to a changing consumer preference pattern that has long been prevalent in poultry and is starting to emerge in pork. *It is without question that an increase in consumers' dollars will be needed to finance a return to growth in the industry.* When prices can be enhanced and a profit margin garnered, then there tends to be a willingness to make investments in product and market development work that has been conspicuously absent in the sheep industry under the open-market pricing system.

Where those investment dollars will come from is a potential complication. It is imperative that producers who get involved in alliances understand that there has to be a significant capital component to the alliance program in order to finance the economic functions that are going to be needed. Producers may try to form a formal cooperative or a less formal group or organization with the idea that each producer would contribute $100 and that would be the capital that is used to finance and start a new endeavor. That is clearly not going to be a sufficient approach to financing. As soon as a part-time manager is needed – because some volume is involved and some merchandising effort starts to be important because you may have parts of the carcass that need to be moved into another market segment – there is no money available to hire that manager and to finance the changes that are needed. *Thus, it is critically important that the participants not underestimate how important the value of a significant capital base will be.* If that capital cannot be raised internal to the industry, then it might be best to approach a professional firm whose job it is to raise money and seek outside investors to capitalize an endeavor that should show considerable profit potential if it is well-conceived, well-planned and well-organized.

It is worth recalling that some of these same ideas have surfaced in the industry in past years. The idea of grabbing control of the situation and getting involved in processing and value-added additions to the product, something that most economists have not advised in the livestock sector in general, has surfaced before in the sheep industry. There seems to be minimal interest in investing in product and market development from the existing set of processors, some of whom are disenchanted with their ability to operate the lamb processing facility at a profit. Lamb appears to be the exception to the general rule in the sense that it may be the case that producers will *have* to get involved in either controlling or owning processing capacity to be able to tailor the product offering and move toward the consumer-friendly status that is needed to capture necessary consumer dollars. But when these ideas were surfaced in past years by some of the professional staff at ASI, they were always met with skepticism and a lack of insight by the producer-oriented councils as to the true nature of the problem that the industry was facing. Nothing was ever done on a local, regional or national basis to move the industry away from the path it was on, and that path was one of continued forced disinvestment and downsizing.

It is not necessary in this Special Issue that any attempt be made to articulate the strategic plan that the industry needs to follow in great detail. The important points that need reemphasizing in closing these observations start with the fact that *producers must come to understand and accept that consumers have turned their backs on lamb products.* It is not sufficient to talk about special sensory characteristics of lamb when the typical modern consumer is not interested in the product offering they are faced with in the supermarket and knows little or nothing about how to prepare it. *It is* *not sufficient to advertise that same product offering and try to convince the consumer to come back to an outdated and outmoded product offering.* That did not work for Chrysler in the late 1970s and 1980s when they went bankrupt before finally realizing they had to change their product offering. That approach also didn't work for IBM in the 1980s when they allowed their PC computer line to move away from a consumer-friendly status and lost virtually all the personal computer market before finally making some changes and restructuring their approach in the early 1990s. It hasn't worked for beef to spend all or most of the scarce check-off dollars on a generic advertising program, spending which recent research shows does nothing to improve beef demand (Brester and Schroeder, 1995). And it will not work for lamb to spend check-off dollars – if a check-off program can be restored to viability – on generic advertising.

What is really needed is to make sure the product offering is consistent with what the modern consumer wants and is willing to pay for. If that can be done and that type of coordination up and down the system can be achieved, then the industry will be back on the road to potential success. It is going to be disturbing to some that success will not come from the traditional open-market price system where product is sold between profit centers as it moves up toward the final consumer. There has always been a fierce allegiance to the "independence" afforded producers in that type of system, and it is still present throughout the industry. But nothing suggests that the open-market pricing system is going to change its level of effectiveness and efficiency and move us back toward a coordinated and effective industry-wide agenda. It would be virtually impossible to change the grading system in the current environment, and any set of descriptors that starts to be used in private firm negotiations will not be consistent from one firm to the next and will not be widely publicized. Thus, if the objective is to move back to viability, it is important that producers, processors and retailers – especially producers – understand the need to organize themselves in the form of alliances that provide the critically important coordination of activity that the pricing mechanism has not been able to provide. If that path is followed, then in the year 2005 and 2010, the sheep industry in the United States could be substantially different and substantially larger than it is today, and producers will have a much better chance of sustaining profits over time.

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Genetic Parameter Estimates for Scrotal Circumference in Ram Lambs and Estimated Covariances with Ewe Body Weight, Fleece Traits and Reproductive Rate

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Summary

Scrotal circumference (SC) of rams was measured at weaning (SCW) and again at the end of a 70-day feed test. The second measurement was analyzed with no adjustments at the time of measurement (SCUNA) and adjusted for body weight (BW) at the time of measurement (SCADJ). Variance components and heritabilities were estimated by MTDFREML. Model 1 included the direct genetic effect in the animal model. Additional analyses also included BW at the time of SC measurement as a covariate for SCW and SCUNA. Traits analyzed for the ewes were for number born per ewe exposed for breeding (NB), number born per ewe lambing (NBL), percentage ewes lambing (%), ewe body weight (EBW), ewe fleece weight (FW) and fleece grade (FG). MTDFREML procedures were used to estimate heritabilities of the ewe traits and to estimate covariances between SCW, SCUNA and SCADJ with the ewe traits. Heritability (h_a^2, Model 1) was 0.24, 0.35 and 0.24 for SCW, SCUNA and SCADJ, respectively. When BW was included as a covariate, h_a^2 was 0.32 for SCW and SCUNA. Genetic correlations with SCUNA (no BW covariate) for NB, NBL, %, EBW, FW and FG were 0.06, 0.18, -0.21, -0.27, -0.51 and 0.47, respectively, and with SCADJ were 0.30, 0.43, 0.03, -0.98, -0.43 and 0.22, respectively. These results show that SC is moderately heritable, and when adjusted for BW has a positive genetic correlation with NB, NBL and FG and a negative genetic correlation with EBW and FW.

Key words: scrotal circumference, reproduction, growth, fleece.

Introduction

Nitter (1987) has shown that increased ewe reproductive rate will improve the economic efficiency of sheep production enterprises by reducing overhead cost per lamb sold. Rate of genetic improvement can be increased by selecting females on the basis of breeding values for reproductive rate (a female sex-limited trait) and additionally selecting males for the same trait using breeding values estimated from information on the productivity of female relatives. However, if an indicator trait in males providing an indirect measure of reproductive rate in females could be identified, selection response could be greatly improved if said trait has a moderate heritability and a high genetic correlation with ewe reproductive rate (Land, 1973). In a review of testis size in sheep, Matos and Thomas (1992) reported the average of 40 estimates of heritability for testicular size to be 0.31, but also indicated there was still some uncertainty as to genetic correlations of testis size with female reproductive traits. In a simulation study, Walkley and Smith (1980) found if the indicator trait of testis size with a moderate heritability and a high genetic correlation with litter size (which has a low heritability) was used in addition to litter size, selection response for litter size could be almost doubled per generation.

The question as to whether measures of testis size should be adjusted for BW, which has a high correlation with testis size, also needs to be addressed. Land (personal communication, 1982) hypothesized that selection for increased SC adjusted for BW would result in progeny with smaller mature sizes. The results of Haley et al. (1990) support this hypothesis.

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The objectives of this study were to estimate genetic parameters for SC with and without BW adjustment and, to estimate the covariance for measures of SC with ewe reproductive, growth and fleece characteristics.

Materials and Methods

Records from 501 Columbia and Rambouillet ram lambs born from 1983 through 1992 were used in this study. The lambs were weaned in mid-August, moved to the Fort Ellis Sheep Experiment Station (Bozeman, MT) and placed on a 70-day feed test. Columbia ram lambs (n = 265) were from two lines being selected for larger SC. The selection criteria for one line was based on SC at approximately 6.5 months of age adjusted for BW (ADJ), while the other line was selected on the basis of SC at the same age with no adjustment for BW (UNADJ). Adjustment equations were estimated using regression procedures (SAS, 1985) with both a linear and quadratic regression of SC on BW of the lamb at the time of measurement. Quadratic effect of BW was not significant ($P > 0.25$); therefore, only the linear term was used to adjust SC for BW. Rambouillet ram lambs (n = 236) were from a random bred control line that was maintained with the Columbia sheep at all times.

Each year, one Columbia ram lamb from each line was selected for use as a sire. Rams were used again the following year. Consequently, two rams were used each year in each line, one ram lamb and one 18-month-old ram. At least half of the ewes assigned to the older ram were females they were exposed to the previous year with the remaining half being selected at random. Sixteen Rambouillet ram lambs (one primary and one reserve ram from each parental half-sib group) were chosen for use as sires each year and used for only one breeding season. The Rambouillet rams were selected using a random number generator with the restriction that no two rams could be full siblings. At breeding, eight rams per year were randomly assigned to ewes when the rams were 18 months old. Additional Rambouillet ram lambs were maintained to make the total number of Rambouillet rams equal to the total number of Columbia rams available. All Columbia ram lambs and an equal number of control ram lambs were placed on a 70-day feed test after weaning.

Breeding of the sheep, shearing, lambing and growth of the lambs through weaning took place at the Red Bluff Research Ranch at Norris, MT. The ranch is characteristic of the mountain foothill area of the Northern Great Plains. Ewes and lambs were managed as a typical range flock, being herded on unfenced pastures all year except when they were brought to the headquarters for data collection, breeding and lambing. Records from matings of 795 Columbia and 942 Rambouillet ewes were used for this study. Ewes were bred beginning the third week of November for a 28-day breeding season with lambing beginning in April and running through May. Ewes were exposed in single sire breeding pens for approximately 20 days, then mass mated to blackfaced rams for the remainder of the breeding season. The overall pregnancy rate to whiteface rams was 86.1% for this group of ewes. From breeding season through lambing, ewes were supplemented with approximately 200 g/head/day of a 20% barley-based supplement with hay being provided only when snow cover was too deep to permit grazing. At shearing in early March, fleeces were weighed and FW recorded. The fleeces were then moved to the Montana Wool Laboratory in Bozeman, MT, where they were visually assigned a spinning count grade (SID, 1992). Lambs were weaned in mid-August at an average age of 122 days and an average weight of 29.6 kg. Ram lambs were moved to the Fort Ellis Sheep Experiment Station in Bozeman, MT, where they were placed on a diet of free choice mixed alfalfa-grass hay and 454 g of barley daily. At weaning, and during the first week of November when the lambs were an average of 196 days of age (end of test), SC was measured with a steel tape by palpating the testes into the scrotum and measuring the circumference at its widest point. Means and standard deviations for the traits of the rams are reported in Table 1.

Ewe reproductive traits have been analyzed and reported as number born per ewe exposed to breeding, number born per ewe lambing and percent of ewes lambing. "Percent of ewes lambing" was calculated by assigning 1 to those that lambed and 0 to those ewes failing to lamb. "Number of lambs born per ewe exposed" was calculated by including those ewes failing to lamb as 0 lambs born and using the actual number of lambs born for those ewes giving birth in the data set. The number of ewe records and mean values for these traits are reported in Table 1.

Variance components and genetic parameters were estimated with the MTDFREML procedure of Boldman et al. (1993). The basic linear model was:

$$Y = X\beta + Zu + e$$

Where:

X = incidence matrix for fixed effects;

β = vector of fixed effects which included selection line of ram (UNADJ, ADJ, control), age of dam (2 through 6 years), year of birth of ram and the covariate age of ram at measurement;

Z = incidence matrix for random effects;

u = vector of random effects (animal genetic); and

e = vector of environmental effects normally and independently distributed $(0, \sigma_e^2)$.

Traits analyzed were each ram's SC at weaning (SCW) and each ram's SC at the end of test. Each ram's SC measurements at the end of test were either the actual unadjusted measurement (SCUNA) or the same measurement adjusted for BW at the end of test (SCADJ). The data were also analyzed with ram BW at time of measurement as an additional covariate for SCW and SCUNA. Model 1 fitted the direct genetic effect in the animal model and was used to estimate heritability (h_a^2).

To determine the importance of adding components to the model, Rao (1973) and Mood et al. (1974) describe a method to compare the ratios of likelihoods from different models. One property of REML methods is that the larger the likelihood function, the better the model explains the variation in the data. The ratio -2[log Λ_i - log Λ_j] is asymptotically distributed as Chi-square, with degrees of freedom equal to the difference in the number of parameters in the models i and j, where Λ is the value of the likelihood function for the model after the convergence criterion was reached. Using this Chi-square value, the difference between models was tested. Model 0, containing only fixed effects with no additive genetic components (σ^2_a), was added to the group of analyses. This was done to test whether σ^2_a accounted for significant genetic variation. The differences in likelihood functions between Models 0 and 1 tested whether the genetic component (σ^2_a) accounted for significant variation.

Multiple trait analyses were used to estimate the genetic covariances among the various measures of SC and ewe reproductive and production traits. A series of bivariate analyses using MTDFREML were run where one trait was a measure of SC and the other trait was one of the ewe traits of interest. Ram traits were analyzed as Model 1 above while for ewe traits the β vector of fixed effects was line of ewe, age of ewe in years and year of the record. In addition, since ewes had repeated records, a non-genetic common environmental component (σ^2_c) was added to the ewe model.

Results and Discussion

Changes in the log likelihood functions between Models 0 and 1 indicated that σ^2_a accounted for a significant ($P < 0.01$) portion of the total variation in all measurements of SC (Table 2). Direct genetic effects (σ^2_a) accounted for 23.6%, 34.8% and 23.8% of the total variation in SCW, SCUNA and SCADJ, respectively, in models without BW included as a covariate. In those models with BW, σ^2_a accounted for 32.2% of the total variation for both SCW and SCUNA. Including BW for SCW and SCUNA resulted in a reduction in σ^2_a of 58% and 63%, respectively, compared to models without BW. However, for σ^2_a in SCW as a result of including BW, proportionally more of the reduction in the variance came from σ^2_e compared to σ^2_a, thus causing h^2_a for SCW to increase from 0.24 to 0.32 for models without BW and with BW, respectively. Table 3 summarizes the estimated variance components for measures of SC. For SCUNA, σ^2_a was reduced proportionally to σ^2_e resulting in similar h^2_a for SCUNA with and without BW in the model.

Heritability estimates for ewe reproductive traits, EBW, FW and FG are shown in Table 4. Genetic correlations of SCW with number born per ewe exposed from models without BW (-0.41) and BW (-0.43) were negative and fairly large. Genetic correlations of SCW with number born per ewe lambing (-0.26) and percent ewes lambing (-0.22) without BW were negative and of moderate size. When BW was added as a covariate the genetic correlation between SCW and number born per ewe lambing was positive and of moderate size (0.26). Genetic correlations between SCUNA and SCADJ with number born per ewe exposed and per ewe lambing were positive. When SCUNA was not adjusted for

Table 1. Number of rams, ewes and ewe records and their means, standard deviations (SD) and coefficients of variation (CV) for each traits studied.

Ram Traits					
Trait	Number of rams		Mean	SD	CV
Weaning:					
SC, cm	627	–	17.4	4.7	27.0
Age, days	627	–	121.6	9.5	7.8
Weight, kg	627	–	29.6	5.6	18.9
End of test:					
SC, cm	498	–	24.0	4.6	19.1
SCADJ, cm	498	–	24.0	3.3	13.8
Age, days	498	–	195.6	6.7	3.4
Weight, kg	498	–	38.8	7.6	19.6
Ewe Traits					
Trait	Number of ewes	Number of ewe records	Mean	SD	CV
Body weight, kg	434	1,365	63.9	7.6	11.8
Number born per ewe exposed	502	1,739	1.2	0.68	56.9
Number born per ewe lambing	464	1,497	1.4	0.52	36.9
Percent ewes lambing	502	1,739	86.1	0.35	40.0
Fleece weight, kg	477	1,512	4.2	0.76	18.5
Fleece grade, spinning count	477	1,512	59.4	5.4	9.2

BW, the genetic correlation with number born per ewe exposed was 0.06 but when SC was adjusted for BW either by using SCUNA with BW as a covariate or adjusting the records prior to analysis (SCADJ), the correlations with number of lambs born were larger, 0.20 and 0.30 for SCUNA and SCADJ, respectively (Table 4). Likewise, the correlation of number born per ewe lambing and SCUNA without BW as a covariate was 0.18 while genetic correlations for SCUNA with BW as a covariate and SCADJ were 0.38 and 0.43, respectively. Waldron and Thomas (1992) reported a genetic correlation of -0.25 between SC (weight adjusted) and litter size similar to the correlation observed in this study between SCW without BW as a covariate and number born per ewe lambing (-0.26). Most of the estimates of the genetic correlation between measures of SC with measures of litter size summarized by Matos and Thomas (1992) were positive and in the range observed in this study for SCADJ with number of lambs born per ewe exposed to breeding and per ewe lambing. Covariances and genetic correlations between measures of SC with EBW were all negative and of greater absolute value when SC was adjusted for BW of the ram. Genetic correlations between SCW and FW were close to zero but with SCUNA and SCADJ were negative and of moderate size. Genetic correlations between FG and SCW were close to zero while correlations between FG and SCUNA adjusted for BW and SCADJ were positive and moderate. The genetic correlation between FG and SCUNA without BW was 0.47 (Table 4).

Estimated heritabilities for measures of scrotal size from this study agree closely with those reported in the review by Matos and Thomas (1992). The positive genetic correlations of SCUNA, with BW as a covariate, and SCADJ with number born also agree with most of their genetic correlations between measures of testis size and measures of female reproduction. The moderate and negative genetic correlation of SCW without BW in the model with number born is difficult to explain, but may relate to the season of measurement (mid-August) or the small proportion that would have attained puberty at this time (note the $\bar{x}$ of SCW was 17.4 cm). This may suggest that prepuberal testis size may not relate to female reproductive traits, but postpuberal testis size may. Estimates of selection response from of ram lambs selected for testis size unadjusted for BW predict that little effect on number born per ewe exposed would be observed. However, these results predict that selection of rams based on testis size adjusted for BW will result in an increase in number of lambs born but a decrease in EBW and in lighter and finer fleeces. This agrees with results from Haley et al. (1990) who reported that response to selection for testis size adjusted for BW resulted in a decrease in BW and an increase in female reproduction; no reports on the genetic relationship between testis size and fleece traits could be found. However, the results of this study are different than those of Haley et al. (1990) in that the primary change in female reproduction they observed was female fertility (percent of ewes pregnant) while in our study the genetic correlations among SC traits and percent ewes lambing were negative or close to zero. In our study, SC may be more closely related to ovulation rate because the genetic correlations were larger for lambs born per ewe lambing (litter size) than for lambs born per ewe exposed or percent ewes lambing, and there is a high genetic correlation between ovulation rate and litter size.

Table 2. Values of $-2[\log \Lambda_i - \log \Lambda_j]$.[a]

Trait	Model 0 – Model 1 w/o BW[b]	Model 0 – Model 1 BW[c]
Between models:		
SCW, cm	7.41[d]	22.83[d]
SCUNA, cm	17.79[d]	24.76[d]
SCADJ, cm	14.06[d]	–

[a] The difference between two different animal models tests the difference between models for scrotal circumference at weaning (SCW), at the end of test unadjusted for body weight (SCUNA) and adjusted for body weight (SCADJ) from models both with (BW) and without body weight (w/o BW) at measurement as a covariate.

[b] w/o BW = body weight not included as a covariate in the model.

[c] BW = body weight included as a covariate in the model.

[d] Chi-square with 1 degree of freedom (df ; P < 0.01).

Table 3. Estimated variance components and heritability estimates for scrotal circumference at weaning (SCW) and scrotal circumference at the end of test either unadjusted for body weight (SCUNA) or adjusted for body weight (SCADJ) both with (BW) and without body weight (w/o BW) at measurement as a covariate.

Parameter[a]	SCW, cm w/o BW[b]	SCW, cm BW[c]	SCUNA, cm w/o BW[b]	SCUNA, cm BW[c]	SCADJ, cm w/o BW[b]
σ^2_a	3.52	2.01	5.82	2.01	1.37
σ^2_e	11.36	4.24	10.88	4.22	4.39
σ^2_p	14.88	6.25	16.70	6.23	5.76
h^2_a	0.24	0.32	0.35	0.32	0.24

[a] σ^2_a = direct genetic effect; σ^2_e = environmental variance; σ^2_p = phenotypic variance; h^2_a = heritability.

[b] w/o BW = ram lamb body weight not included as a covariate in the model.

[c] BW = ram lamb body weight included as a covariate in the model.

Waldron and Thomas (1992) reported the genetic correlation between ovulation rate and litter size was 0.96 while Burfening and Davis (1995) reported the genetic correlations between ovulation rate and lambs born per ewe exposed was 0.60 and lambs born per ewe lambing was 0.93. Further, these studies offer strong support for the contention of Lee et al. (1991) that selection for testis size would be a method by which an early indicator of maturity could be evaluated with animals selected having a smaller mature size yet higher reproductive rate thus making them more efficient. However, the negative correlation between testis size adjusted for BW and FW is disturbing for use in flocks where fleece production is an important component of the producers' economic returns. This negative genetic correlation may be the result of a positive phenotypic relationship between BW and FW where larger ewes produce more fleece.

Although the physiological reason for a negative genetic correlation between measures of testis size adjusted for BW and EBW are unclear, there is a possible explanation. In young rams as with other animals, testis size is related to age at puberty and age at puberty is also related to maturity and mature size. Selecting rams for testis size adjusted for BW results in selecting rams with large testis sizes relative to BW. These rams would have reached puberty at a smaller BW therefore having a smaller mature size. Mature size is a highly heritable trait; thus their daughters would also have a smaller mature size. This decrease in mature size is potentially desirable since smaller ewes should have a reduced maintenance requirement but produce more lamb. However, if decreasing mature size were considered to be undesirable then perhaps a restricted selection index that would increase scrotal size while holding BW constant should be evaluated.

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Table 4. Estimated covariance components σ_d and genetic correlations r_d between measures of scrotal circumference at weaning (SCW), unadjusted for ram body weight (SCUNA) and adjusted for ram body weight (SCADJ) with (BW) and without (w/o BW) ram body weight included as a covariate for SCW and SCUNA with measures of ewe lambing rate, body weight and fleece traits.

		Ewe Traits[a]					
Trait	Component[b]	NB	NBL	%	BW, kg	FW, kg	FG, score
Ewes:							
	σ_a^2	0.05	0.03	0.00	18.10	0.23	3.76
	σ_e^2	0.00	0.00	0.01	14.99	0.02	0.67
	σ_p^2	0.37	0.21	0.10	14.69	0.09	6.55
	h_a^2	0.12	0.12	0.01	0.38	0.67	0.34
Rams:							
SCW:							
w/o BW	σ_a	-0.151	-0.084	-0.046	-2.02	-0.09	1.35
	r_a	-0.41	-0.26	-0.22	-0.27	-0.10	0.10
BW	σ_a	-0.153	0.063	0.010	-3.90	0.04	-0.08
	r_a	-0.43	0.26	0.07	-0.69	0.06	-0.03
SCUNA:							
w/o BW	σ_a	0.026	0.071	-0.055	-2.63	-0.56	2.10
	r_a	0.06	0.18	-0.21	-0.27	-0.51	0.47
BW	σ_a	0.056	0.093	0.008	-4.81	-0.23	0.63
	r_a	0.20	0.38	0.05	-0.87	-0.34	0.23
SCADJ:							
w/o BW	σ_a	0.069	0.087	0.004	-4.45	-0.23	0.47
	r_a	0.30	0.43	0.03	-0.98	-0.43	0.22

[a] NB = number born per ewe exposed; NBL = number born per ewe lambing; % = percent ewes lambing; BW = body weight.; FW = fleece weight; and FG = fleece grade.

[b] σ_a^2 = direct genetic effect; σ_e^2 = environmental variance; σ_p^2 = phenotypic variance; h_a^2 = heritability; σ_a = covariance; and r_a = covariance.

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Seroprevalence of Ovine Progressive Pneumonia in Texas

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Summary

Ovine progressive pneumonia (OPP) is a chronic debilitating disease of sheep caused by ovine lentivirus (OvLV). To determine the prevalence of antibodies against OvLV in Texas sheep, serum samples were collected from 2,040 animals in or near the Edwards Plateau, an approximately 20 million acre area in west Texas where over 90% of all sheep in Texas are raised. The population sampled included 504 sera from yearling rams participating in the Texas Agricultural Experiment Station Ram Performance Test (TAES-RPT) and 1,536 sera collected at 28 locations throughout the Edwards Plateau. Of the animals tested, 65% were females and 67% of all sheep tested were Rambouillets. Other breeds of sheep included Suffolk (14.5%), Booroola Merinos (4%), Finn-Dorset (3.9%) and various breeds and crosses (10.6%). The average age of the sheep tested was 32.5 months. The origin of 64 of the sheep tested could be traced to states other than Texas.

Of the total 2,040 sera tested, ten (0.5%) were found positive for OvLV precipitating antibodies. Eight of the positive samples belonged to animals that had been introduced into Texas from other states. A Suffolk ram acquired at an auction and thought to have originated from another state was also positive. One six month-old lamb, which was the result of the mating between this ram and a Rambouillet ewe, was the only confirmed-Texas-born sheep positive for OvLV antibodies.

Due to low prevalence of OvLV in our sample, no relationships other than a significant ($p < 0.05$) risk for OvLV antibodies in sheep that originated out-of-state, could be established. It is assumed that the low prevalence of OvLV antibodies in Texas sheep may be due to the practice of lambing under extensive conditions in the range. The hot and dry weather of west Texas and the practice of most Texan producers of acquiring replacement sheep, particularly ewes, within the state of Texas may also be contributing factors to the low prevalence of OvLV antibodies. However, the introduction of infected sheep into Texas flocks may represent a risk for spreading the infection.

Key words: ovine lentivirus, ovine progressive pneumonia, seroprevalence, Texas.

Introduction

Ovine progressive pneumonia (OPP) is a chronic debilitating disease of sheep caused by ovine lentivirus (OvLV), an exogenous non-oncogenic retrovirus. In addition to lymphoid interstitial pneumonia, OvLV also may cause regional lymphadenomegaly, indurative lymphocytic mastitis, proliferative arthritis and less frequently non-suppurative encephalitis (de la Concha-Bermejillo, 1997). Ovine progressive pneumonia is considered to be one of the most important diseases affecting sheep in North America (de la Concha-Bermejillo et al., 1997). Economic losses due to OPP may be the result of animal deaths, treatment of sick animals, reduced production parameters and loss of trade due to restrictions in international markets (Petursson et al., 1990; Petursson et al., 1992; Smith, 1992; Pekelder et al., 1994).

Several factors, including climate and management, may influence the rate and mode of transmission of OvLV. From field studies, it is evident that OvLV spreads laterally, probably by the respiratory route. In flocks where the infection is enzootic, a route of infec-

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tion seems to be from ewe to lamb through infected colostrum (Petursson et al., 1992). Although less common, vertical transmission from mother to fetus has also been reported (Georgsson et al., 1978; Cutlip et al., 1981; Cutlip et al., 1982; Carey and Dalziel, 1993; Brodie et al., 1994). Venereal transmission of OvLV has not been reported; however, recent information indicates that OvLV-inoculated animals co-infected with Brucella ovis can shed the virus in the semen (de la Concha-Bermejillo et al., 1996).

In one recent report, the U.S. average OPP seroprevalence in 17,000 sheep sera from 29 states was 26%, although there was a wide range of variation among states and among individual flocks (Cutlip et al., 1992). In this study (which did not include sera from Texas sheep), the highest OvLV seroprevalence was in the Rocky Mountain region at 49% with the lowest seroprevalence in the Northern Atlantic region at 9%. The percentage of seropositive animals increased with age from 4% at less than 1 year to a plateau of 34% at 4 years. Previously, a study of culled ewes from Western and Midwestern states reported the OvLV seroprevalence to range from 1 to 68% (Cutlip et al., 1977). In that survey, the prevalence of OPP in a small sample of 120 sera collected from Texas and Oklahoma sheep was found to be 1%. The objective of the present study was to conduct an epidemiological survey to determine the prevalence of OPP in Texas and to ascertain the risk factors associated with OvLV infection in this state.

Materials and Methods

Study Population

A total of 2,040 sheep serum samples were collected from 31 west Texas counties in or around the Edwards Plateau (an approximately 20 million acre area in west Texas where over 90% of all sheep in Texas are raised). Five hundred and four of these samples were collected from yearling rams participating in the 1991 and 1992 TAES-RPT and belonged to 56 different owners. The other 1,536 serum samples were collected from 28 different locations in west Texas. Participants in this second group were selected on the basis of location (North, South, East, West), breed of sheep, size and management practices of the farm/ranch as well as willingness of the owner to participate.

Sampling and Testing Method

Blood was collected once from each sheep by jugular venipuncture. At the time of blood collection the age, breed, sex, place of origin (Texas vs. out-of-state) of each animal were recorded. In those cases where an exact date of birth could not be obtained, the age of the animal was determined by dental examination and adjusted to the nearest year as 1, 2, 3, 4, 5, 6 or older. For those animals from which blood was collected at specific locations, in addition to obtaining the above-mentioned information, a questionnaire containing information about the location of the property, the total number of animals and species (ovine, caprine, bovine), type of farm/ranch (breeding or feedlot), type of lambing (range, shedding, enclosed), time of lambing (fall, winter), use of needles (single vs. multiple use) to vaccinate animals and replacement practices was completed.

Blood samples were transported to the Veterinary Lab at the Texas Agricultural Experiment Station in San Angelo, TX, and serum separated by centrifugation within 16 hours of collection. Samples were stored at -70 °C and tested for the presence of OvLV precipitating antibodies by the agar gel immunodiffusion (AGID) test using a commercially available kit (Veterinary Diagnostic Technology, Inc., Wheat Ridge, CO 80033). Test results were read as negative (-) or positive (1+, 2+, 3+) depending on the precipitin line. A 1+ reaction was a faint hook in the precipitin line between the positive control serum and antigen wells, a 2+ was a faint line between the test serum and antigen wells (usually closer to the former) and a 3+ reaction was a dense precipitin line of identity with the positive controls on either side.

Data Analysis

The Chi-Square test was used to determine differences between sets of data.

Results and Discussion

Results

Of the 2,040 serum samples tested for the presence of OvLV precipitating antibodies, 10 samples (0.49%) were found to be positive. The characteristics of the OvLV positive sheep are summarized in Table 1. Eight of those positive samples belonged to sheep that had been brought to Texas from other states. Three 2-year-old Finn-Dorset rams imported from Missouri were found positive on one breeding ranch of approximately 2,000 animals. All the lambing at this ranch occurred on the range during the spring and the average lamb crop varied from 110% overall to 135% in the Finn crosses. Several rams from Missouri and Kansas had been introduced into the flock on this ranch. The 3 OvLV-positive rams had been introduced into the ranch approximately 2 years before they were

Table 1. Characteristics of ten Texas sheep found positive for ovine lentivirus antibodies by the agar gel immunodiffusion (AGID) test.

Number	Breed	Age[a]	Sex	State of origin	AGID test
91R0321	Suffolk	72	M	Idaho	+
91R0388	Suffolk	48	M	Auction	+++
91R0948	Suffolk	84	F	Iowa	+++
91R0951	Suffolk	48	F	Iowa	+++
91R0952	Suffolk	84	F	Iowa	++
92R0695	Finn-Dorset	24	M	Missouri	+
92R0696	Finn-Dorset	24	M	Missouri	+
92R0697	Finn-Dorset	24	M	Missouri	+++
92R0831	Polypay	36	F	Missouri	+++
92R0581	Suffolk-Cross	6	M	Texas	+

[a] Age in months.

tested. Management practices on this ranch, although excellent, did not include OvLV testing. After reporting the results to the owner, all three positive rams were removed from the premises and 189 animals in contact with the rams were tested and found negative for OvLV. Subsequent retesting of those animals in contact with the infected rams was done 3, 6 and 12 months later and still no positive animals were found. In addition, this ranch has adopted the practice of testing new animals for OPP before they are brought to the premises.

A Polypay ewe introduced from Missouri to a small farm of 28 animals in Ellis County, TX, was also found to be positive. The purpose of this farm was to breed colored-wool sheep and frequently introduced animals from other states or acquired them at auctions without testing for OPP. Management on this farm consisted of lambing in open pens or pastures. Seventeen other sheep tested from this location were found negative for OvLV antibodies. The positive ewe was removed from the premises, but animals in this property were not retested since then as part of this study.

The fifth positive animal was a Suffolk ram brought along with two other Suffolk rams from Idaho and introduced into a ranch of approximately 2,000 animals in McCulloch County, TX. Management in this ranch was typical of a large breeding sheep ranch in west Texas. Sheep were run together with beef cattle and goats under extensive conditions with most of the lambing occurring on the range during the winter and some during the fall. The majority of the animals in this flock consisted of Rambouillet ewes bred to Rambouillet or Suffolk rams. Only occasionally were out-of-state Suffolk rams introduced into this ranch, with all the replacement ewes being acquired from their own flock or other ranches in Texas. No Suffolk crossbred ewes were retained. The average lamb crop was approximately 110%. Drenching and vaccination against soremouth and enterotoxemia were the only health management practices. Two hundred and five sheep in contact with the OPP positive ram were negative for OvLV by the AGID test.

Table 2. Characteristics of the sheep population tested for ovine lentivirus antibodies in Texas.

Characteristic	TAES-RPT[a]	Other locations	Total (%)
Numbers:			
Total sheep	504	1,536	2,040 (100)
OPP positive	0	10	10 (0.5)
OPP negative	504	1,526	2,030 (99.5)
Sex Distribution:			
Male	504	218	722 (35.4)
Female	0	1,318	1,318 (64.6)
Breed Distribution:			
Rambouillet	504	862	1,366 (67)
Suffolk	0	296	296 (14.5)
Booroola Merino	0	85	85 (4)
Finn-Dorset	0	79	79 (3.9)
Others	0	214	214 (10.6)
Age Distribution:			
Less than 1 year	243	179	422 (20.9)
Less than 2 years	247	225	472 (23.3)
Less than 3 years	0	254	254 (12.6)
Less than 4 years	0	234	234 (11.6)
Less than 5 years	0	161	161 (7.8)
Less than 6 years	0	253	253 (12.5)
Older than 6 years	0	224	224 (11)
Origin:			
Texas -/+	504/0	1,470/1	1,974/1 (0.05)[b]
(% OPP +)	(0)	(0.07)	
Out of State -/+	0/0	56/8	56/8 (12.3)[c]
(% OPP +)	(0)	(12.5)	
Auction -/+	0/0	0/1	0/1 (100)[d]
(% OPP +)	(0)	(100)	

[a] TAES-RPT = Texas Agricultural Experiment Station Ram Performance Test.

[b,c,d] Differences between different superscript letters are significant ($p < 0.0004$; Chi-square = 12.89).

From fourteen animals bled in a feed yard, three Suffolk ewes (one 4-year-old and two 7-year-olds) from Iowa and that were in transit to another location outside Texas, were positive for OvLV. The ninth positive animal was a 4-year-old Suffolk ram that had been bought at an auction in west Texas and introduced to a ranch in Concho County, TX. The owner of this animal could not identify the state in which the animal had originated, but suspected that it had been brought from out-of-state. One hundred and forty-nine Rambouillet ewes, 39 lambs and one other Suffolk ram resulted negative to OvLV when tested 8 months after the OvLV positive ram had been removed from the ranch. However, one wether lamb (the tenth positive) that resulted from the mating of the infected ram to Rambouillet ewes was OvLV-positive when tested at 6 months of age.

The characteristics of the sheep population tested for OvLV antibodies in Texas are presented in Table 2. A total of 2,040 sheep from 78 owners in 32 counties were tested. Sixty-five percent of the animals tested were females and 67% of all sheep tested were Rambouillets. Other breeds of sheep included Suffolk (14.5%), Booroola Merinos (4%), Finn-Dorset (3.9%) and various breeds and crosses (10.6%). The average age of the sheep population was 32.5 months. The origin of 64 of the sheep tested could be traced to states other than Texas. The prevalence of OPP in this group of sheep was 12.5%. If the OPP positive ram acquired at an auction is included in the group of out-of-state animals, the prevalence in this out-of-state group increases to 13.8%.

Samples collected from rams participating in the TAES-RPT included 504 animals from 56 owners in Texas. The average age in this group was 10.7 months, all were Rambouillet. Samples collected from specific locations in or around the Edwards Plateau in west Texas included 1,536 animals from 28 different locations. The average age in this group was 39.5 months. Twenty-six of these twenty-eight locations were breeding ranches, one was a feed yard and one was a ranch/feedlot operation. Sixteen practiced range/pasture lambing exclusively, six practiced shed lambing, three practiced a combination between range and shed lambing and two places lambed in enclosed facilities. Thirty-three percent lambed during the winter and spring, 25% during the winter, 25% during the spring, 13% during the fall and winter and 4% most of the year. Responses from sixteen locations indicated that although sheep had been introduced from other states, they were few and the majority were rams of breeds other than Rambouillet. Vaccinations included soremouth and enterotoxemia. All owners in these locations indicated that they used the same needle to vaccinate or treat several animals. Eight locations indicated that for the last five years they had only acquired replacement sheep from Texas ranches and one owner kept a closed flock. The total number of sheep in each of the 28 locations ranged from 9 to 7,000 with an average of 1,120 sheep per location that represented a population of 30,205 sheep. The percentage of animals tested in each location ranged from less than 1 up to 100% (average = 28.5%).

Discussion

The prevalence of OvLV antibodies in the sera of sheep from Texas in our study was 0.5%. Our sample included 2,040 sera from sheep that were kept in or around the Edwards Plateau and from premises with a wide diversity of management practices. The Edwards Plateau encompasses an area of approximately 20 million acres in west Texas bounded by Austin on the east and the Pecos River on the west, by the Rio Grande river on the south and the Rolling Plains on the north. Within the Edwards Plateau there is a considerable variability in plant, animal, soil and climatic resources. For instance, the average annual rainfall will vary from as little as 12" in the south and west to over 30" in the east (Shelton, 1991).

In this survey, the origin of eight of the 10 seropositive animals could be traced back to states other than Texas, and the difference in OvLV prevalence between Texas-native (0.5%) and out-of-state (12.5%) sheep was highly significant ($p < 0.0004$). If the OvLV-positive ram obtained at an auction is included in the out-of-state group, the prevalence of OvLV in this group rises to 13.8%. The overall prevalence of OvLV in our survey is similar to the 1% previously reported in 120 sheep sera from Texas and Oklahoma (Cutlip et al., 1977). Due to the small number of positive samples in our study, no other relationships could be established.

In the U.S., the average reported seroprevalence in 17,000 sheep sera from 29 states – Texas not included – was 26%; however, the range of variation among states and among individual flocks was wide (Cutlip et al., 1992). In that study, the highest OvLV seroprevalence was in the Rocky Mountain region at 49% and lowest in the Northern Atlantic region at 9%.

The reasons for the difference in OvLV prevalence rate between Texas and other states are not clear but may be attributed to several factors, such as the practice of most Texas producers to lamb on the range. Ewes that are lambing on the range tend to segregate from the rest of the flock, thus preventing other animals from coming into contact with infected uterine blood and fluids that contaminate the premises during parturition. In addition, because of the mostly hot and dry weather in the Edwards Plateau, the infectivity of infected blood in hot climates may be lost sooner than in cold climates.

Ovine lentivirus can be transmitted through vertical or horizontal routes (de la Concha-Bermejillo, 1997). However, the importance of each of these routes in the epidemiology of OPP is still unclear. Because OvLV can be detected in the milk of infected ewes, and the artificial rearing of ovine colostrum-deprived lambs is considered to be an effective method for the control of OvLV infections, some investigators consider that vertical transmission through the ingestion of OvLV-infected colostrum and milk is the most important way of OvLV transmission (Ouzrout and Lerondelle, 1990; Petursson et al., 1992; Brodie et al., 1994; Juste et al., 1997). However, milk transmission rates should be similar between sheep raised in cold and hot/dry climates, or between sheep raised in close confinement and wide open spaces. Because a positive correlation has been found between the proportion of sheep seropositive to OvLV and age of infected animals, other investigators consider that horizontal transmission through close contact is the most important route of OvLV transmission (Simmard and Morley, 1991; Cutlip et al., 1992). The majority of sheep in Texas are raised in wide open spaces throughout the year; therefore, close contact between infected and non-infected animals is less likely to occur, particularly during the time of winter lambing. Thus, the low prevalence of OvLV antibodies in Texas sheep supports the theory that transmission through aerosols and/or contaminated premises during lambing, exacerbated by cold weather and closed housing practices, may be the most important avenues of OvLV transmission. Nevertheless, the possibility that cold weather and close confinement could predispose infected ewes to mastitis and increased shedding of OvLV in the milk needs to be considered. For instance, it has been shown that virus load and leukocytospermia are both predisposing factors for the shedding of OvLV in the semen of infected rams (de la Concha-Bermejillo et al., 1996). Similarly, an increase in leukocyte counts in the milk of ewes with mastitis could be a predisposing factor for the shedding of OvLV in milk.

In our survey, 67% of the total sheep tested were Rambouillets and none of them were seropositive for OvLV. It has been speculated that Rambouillets are less susceptible to OvLV infection than other breeds (Houwers et al., 1989). However, some of those results may be difficult to interpret because the exposure histories are somewhat uncertain. Most likely this finding reflects the fact that most Rambouillet replacement sheep are acquired within the state, while replacements for other breeds are frequently acquired from other states. In a 10-year retrospective study in a large range flock, the OvLV seroprevalence in Rambouillet and Targhee sheep, which initially was lower than the flock average, moved toward the flock average of 47%, indicating that length of exposure may play a more important role in seroprevalence rates among different breeds (Smith, 1992).

At the time of this survey, there were approximately 2 million sheep in Texas (U.S. Sheep Industry, Market Situation Report, 1990 to 1991). Because more than 90% of all sheep in Texas are raised in the Edwards Plateau, the animals tested in this study represent a good cross-sectional sample of the ecological diversity in which sheep are raised in Texas. However, the 2,040 animals tested in this study represent only 0.1% of the sheep population in this state. In order to obtain accurate information on a disease with an expected prevalence rate of 1%, over 15% of the population should be tested (Smith, 1995). Testing more than three hundred thousand sheep in Texas would be economically unfeasible. Nevertheless, based on the results of this survey and a previous one (Cutlip et al., 1977), and because of the lack of clinical and pathological evidence of OvLV-induced disease in Texas native sheep (de la Concha-Bermejillo, unpublished observation), we can conclude that the prevalence of OPP in Texas is close to our estimated result.

Several reports indicate that the sensitivity of the AGID test is low (Houwers et al., 1982; Zanoni et al., 1991; Kwang et al., 1993); however, a recent report found that the sensitivity of the AGID test used in our study is comparable to that of recombinant ELISA (Juste et al., 1995). In addition, other published OvLV surveys done in the United States have used the same test (Gates et al., 1978; Madewell et al., 1990; Cutlip et al., 1992). Therefore, the differences in OvLV seroprevalence between states cannot be attributed on the type of test used in this survey.

Conclusions

In this study, we found only one Texas-native sheep positive for OvLV. Approximately one year before the testing, an infected ram had been introduced to the ranch where that animal was found. Because the ram and the lamb were never in direct contact, we can rule out that the ram infected the lamb. Because the lamb had already been weaned by the time it was tested, and we did not find another positive animal on this ranch, we can only speculate that the lamb acquired the virus/antibodies through its mother, and that possibly the ewe acquired the infection from the ram at the time of breeding. Nevertheless, the fact that we found this positive Texas-native lamb suggests that transmission of OvLV under Texas climatic and management conditions may occur.

Because most Texas sheep producers only occasionally acquire out-of-state replacements and in the majority of cases the replacements are rams, the risk of spreading OvLV in the native Texas sheep population seems to be low. However, recent evidence indicates that OvLV may be present in the semen of infected rams when the ejaculate is contaminated with leukocytes (de la Concha-Bermejillo et al., 1996). Furthermore, as a result of the low prevalence of OPP in Texas, most producers in this state may have a competitive advantage when marketing registered animals because OPP is a disease of great concern to the national and international communities (de la Concha-Bermejillo, 1997). However, because of changing demographics, production objectives and management practices in the sheep industry, screening of new animals for OvLV is highly recommended in order to maintain OvLV-free flocks in Texas.

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Increased Shear Values of Callipyge Loin Chops Are Related to Cooking Effects

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Summary

We investigated the effects of phenotype, muscle type and cooking on the shear values of lamb chops. There was a significant (P = 0.03) interaction of phenotype with final internal temperature on shear values of the cooked loin chops. Among those loin chops left raw or cooked to final internal temperatures from 45 to 55 °C, chops from callipyge lambs had shear values similar (P = 0.25) to chops from normal animals. Among those loin chops cooked to internal temperatures from 60 to 80 °C, chops from callipyge lambs had higher (P < 0.01) shear values than chops from normal lambs. The difference in mean shear values between loin chops from callipyge and normal lambs increased linearly as internal temperature increased from 60 to 80 °C ($r^2 = 0.98$, P = 0.01). Loin chops from callipyge lambs required longer (P < 0.01) cooking times to reach the same internal temperature as chops from normal lambs. In contrast, there was no difference (P = 0.50) in shear values between the cooked (70 °C internal) chops from the biceps femoris (leg) of callipyge and normal lambs. As compared to raw chops, cooking increased (P = 0.03) the shear values of the loin chops, but decreased (P = 0.02) the shear values of the leg chops, respectively. Taken together, these results suggest that the basal cause of toughness in loin chops from callipyge as compared to normal lambs is due, at least in part, to the toughening effect of longer cooking times on the myofibrillar proteins. This effect was not observed in chops from the leg, probably because tenderness in these cuts is determined by their connective tissue rather than their myofibrillar proteins.

Key words: sheep, callipyge, meat, tenderness, cooking.

Introduction

The cooked loin chops (longissimus muscle) from callipyge lambs have higher shear values than chops from normal lambs (Koohmaraie et al., 1995; Carpenter et al., 1996; Field et al., 1996; Shackelford et al., 1997) and unacceptable sensory tenderness (Jackson et al., 1994; Rawlings et al., 1994; Clare et al., 1997). In contrast, leg roasts from callipyge lambs have sensory tenderness similar to that of leg roasts from normal lambs (Rawlings et al., 1994; Shackelford et al., 1997). The reason for toughness of callipyge loin chops is not clear but may be related to muscle type, cooking method and final internal temperature achieved during cooking; these are important factors determining the tenderness of any meat (for review see: Kropf and Bowers, 1992). In this study, we investigated the effects of phenotype, muscle type and cooking on the shear values of grilled lamb chops.

Materials and Methods

Animals

Normal Rambouillet ewes and normal Suffolk ewes were mated with heterozygous callipyge rams that were 1/8 Dorset × 7/8 Rambouillet to produce animals for this project. Progeny were visually classified as "callipyge" or "normal" based on muscle conformation in the hind saddle and loin areas beginning at three weeks of age until slaughter. Phenotypes were verified based on inheritance of genetic marker alleles associated with the callipyge gene (Cockett et al., 1994 and 1996). When the ram lambs (n = 9 callipyge; n = 10 normal) reached approximately 58 kg liveweight, they were slaughtered at Utah State University (Logan, UT) under USDA inspection guidelines.

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The loin was removed from each carcass at 24 hours after death, cut in half lengthwise using a band saw, wrapped in plastic and butcher paper and frozen at -20 °C for 3 to 4 months. The biceps femoris muscle was removed from one leg of each carcass, wrapped in plastic and butcher paper and frozen at -20 °C for 3 to 4 months.

Experimental Design

Chops (2.54 cm thick) were cut from the frozen half-loins using a band saw and allowed to thaw at 2 °C for 24 hours. One randomly selected chop from each half-loin (two chops per animal) was left raw. Seven chops from each loin were cooked on a grill (140 °C surface temperature), each chop to a randomly assigned internal temperature of 45, 50, 55, 60, 65, 70 or 80 °C. The internal temperature of the chops was monitored using a type K copper-nickel thermocouple inserted into the center of each chop and attached to an Easy Logger System recorder (Omnidata International, Logan, UT). Chops were flipped only once at predetermined internal temperatures of 30, 32, 35, 40, 45, 48 and 50 °C corresponding, in order, to the specific final internal target temperatures. To allow for the rise in temperature that occurred after the chops were taken off the grill, chops were removed to a plate when the temperature was 1 to 2 °C less than the target temperature. Cooked chops were allowed to cool to 21 °C and two 1.27-cm cores were removed perpendicular to the chop for determination of shear values. Shear values were measured using a Warner-Bratzler shear device (G-R Electric Manufacturing Company, Manhattan, KS). To minimize deformation of chops during coring that can lead to cores not having a uniform diameter, special care was taken to surround and contain the outside of the chops with the fingers of one hand when removing cores. Any cores not having a uniform diameter were discarded. Raw chops were cored while still partially frozen. The data were analyzed by MANOVA with phenotype (normal vs. callipyge) as a between-group factor and with internal temperature (raw, 45, 50, 55, 60, 65, 70, 80 °C final internal temperature) as a within-animal factor.

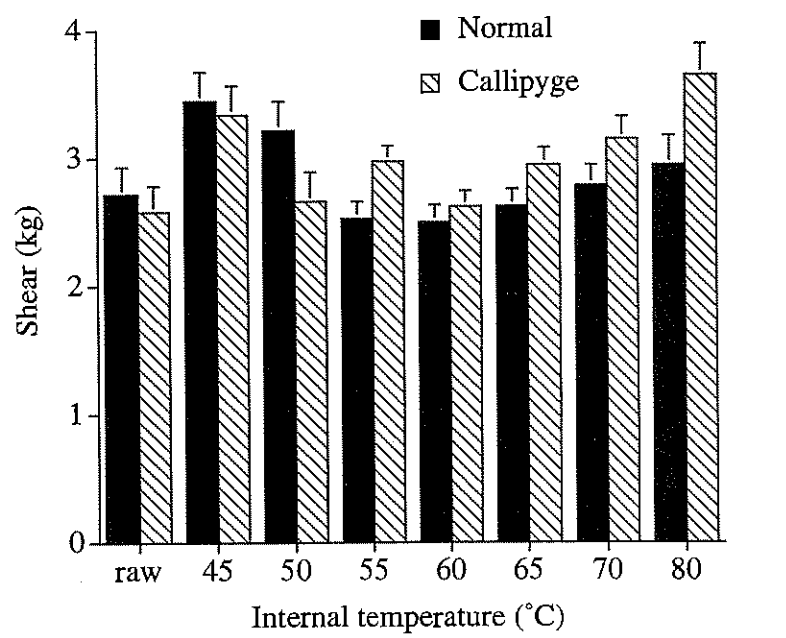
For loin chops cooked to 80 °C, internal temperature was logged every minute until the target internal temperature was attained. Raw data were used to calculate the time it took to reach internal temperatures of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 and 70 °C. The main effect of phenotype (normal vs. callipyge) on the time to reach the internal temperatures was determined by ANOVA.

Leg chops (2.54 cm thick) were cut from the frozen biceps femoris muscles using a band saw and allowed to thaw at 2 °C for 24 hours. Two chops from each muscle were left raw and two chops were cooked on a grill (140 °C surface temperature) to an internal temperature of 70 °C. The internal temperature of the chops was monitored using a thermometer inserted into the center of each chop. Cooked chops were allowed to cool to 21 °C and two 1.27-cm cores were removed from each chop for determination of shear values. The data were analyzed by MANOVA (STATISTICA/Mac program; Stat Soft Inc., Tulsa, OK). Phenotype (normal vs. callipyge) was a between-group factor, and cooking (raw vs. cooked) was a within-animal factor.

Results and Discussion

Cooking to 80 °C increased ($P = 0.03$) the shear values of cooked loin chops as compared to raw chops (Figure 1). The pattern of shear force for loin chops cooked to the different internal temperatures was typical of the two-phase toughening expected when cooking muscles, such as longissimus, that have a relatively low content of connective tissue (for review see: Kropf and Bowers, 1992). During initial heating to 45 °C, shear values first increased ($P < 0.01$), probably due to the shrinkage of the myofiber and loss of myosin solubility. With continued heating to 55 and 60 °C, shear values decreased ($p < 0.01$), possibly due to changes in the connective tissue (Bouton et al., 1981). When internal temperatures of 60 to 80 °C were achieved, shear values again increased ($P < 0.01$), as

Figure 1. Mean shear values of raw and cooked lamb loin chops.[a]



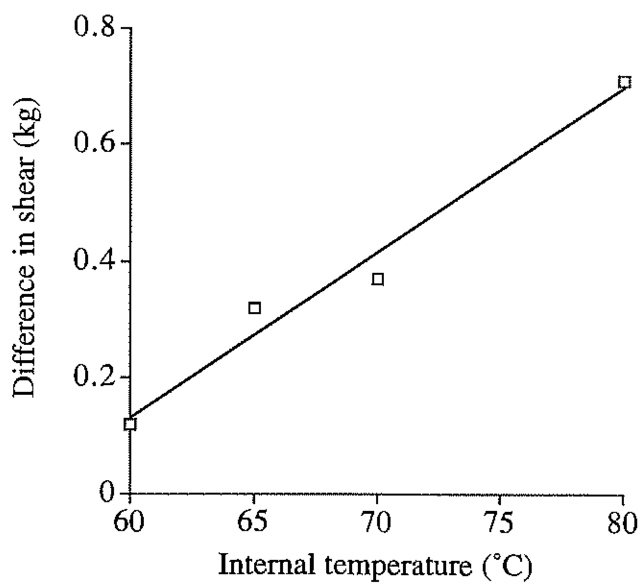
[a] Cooked chops (80 °C) had higher ($P = 0.03$) shear values than raw chops. For the raw chops and chops heated to 45 and 50 °C, callipyge and normal chops had similar ($P = 0.25$) shear values. For the chops cooked to 55 °C and greater, callipyge chops had higher ($P < 0.01$) shear values than the normal chops. Error bars equal SEM (n = 9 callipyge lambs, n = 10 normal lambs).

expected, likely due to hardening of the myofibrillar proteins. The temperatures at which shear values increase differ depending on several factors including the species of animal, the muscle, the method of heating and the method of measuring shear (for review see: Kropf and Bowers, 1992). Thus, it is not unreasonable that the phases of increasing shear occurred 5 to 10 °C lower than expected for meat in general, but based largely on experiments with beef.

There was a significant ($P = 0.03$) interaction of phenotype with final internal temperature on shear values of the cooked loin chops (Figure 1). Visual inspection of the shear values by treatment groups indicated that the interaction was not orderly. For that reason the treatment groups were pooled by internal temperature to produce two groups, each having no interaction of phenotype with final internal temperature of the chops. The first pooled group included the raw chops and those chops cooked to 45 or 50 °C. Within this group, loin chops from callipyge lambs had shear values similar ($P = 0.25$) to shear values of loin chops from normal lambs. Shear values of raw and slightly cooked meats, which are highly compliant during shearing, largely reflect the tensile resistance of connective tissue (Lepetit and Culioli, 1994). Thus, the similarity of shear values of raw and slightly-cooked loin chops from callipyge and normal lambs is consistent with the similarity in content of collagen in longissimus from callipyge and normal lambs (Field et al., 1996).

The second pooled group included those chops cooked to 55 °C or higher, temperatures that cause thermal denaturation of the major myofibrillar proteins (for review see: Kropf and Bowers, 1992). Within this group, loin chops from callipyge lambs had higher shear values ($P < 0.01$) than loin chops from normal lambs. The difference in mean shear values between chops from callipyge and normal lambs increased linearly as internal temperature increased from 60 to 80 °C (Figure 2). Shear values of cooked meat reflect the coupled rupture of both connective tissue and myofibrillar components (Lepetit and Culioli, 1994). Considering the relatively small connective tissue component in longissimus (for review see: Kropf and Bowers, 1992), and considering the temperature range at which the higher shear values of callipyge chops became evident, the higher shear values of callipyge chops is likely related to an interaction of cooking with their myofibrillar proteins.

Figure 2. Differences in the mean shear values of loin chops from callipyge and normal lambs cooked to the same internal temperature.[a]



[a] $r^2 = 0.98$; $P = 0.01$.

Loin chops from callipyge lambs required longer ($P < 0.01$) cooking times to reach the same internal temperature as chops from normal lambs (Figure 3). It has long been realized that the longer the time a protein is maintained at temperatures capable of inducing denaturation, the more extensive the denaturation of the protein (Harland et al., 1952; DeMan, 1985). Thermal denaturation of myosin, the major myofibrillar protein, begins at about 60 °C (Kropf and Bowers, 1992) and it took the chops from callipyge lambs about twice as long to increase from 60 to 70 °C as it took the chops from normal lambs (7.4 vs. 3.9 minutes, respectively). Thus, it is reasonable to hypothesize that the higher shear values of loin chops from callipyge lambs are, at least in part, the result of longer cooking times and greater denaturation of the myofibrillar proteins. The reason for longer cooking times of chops from callipyge lambs was not clear, but may be related to the lower concentration of fat and/or the greater size of chops from callipyge animals. Decreased intramuscular fat is associated with increased cooking times of beef steaks, probably due to less heat being carried by the intramuscular migration of liquid fat during cooking (Cross, 1977; Kropf and Bowers, 1992).

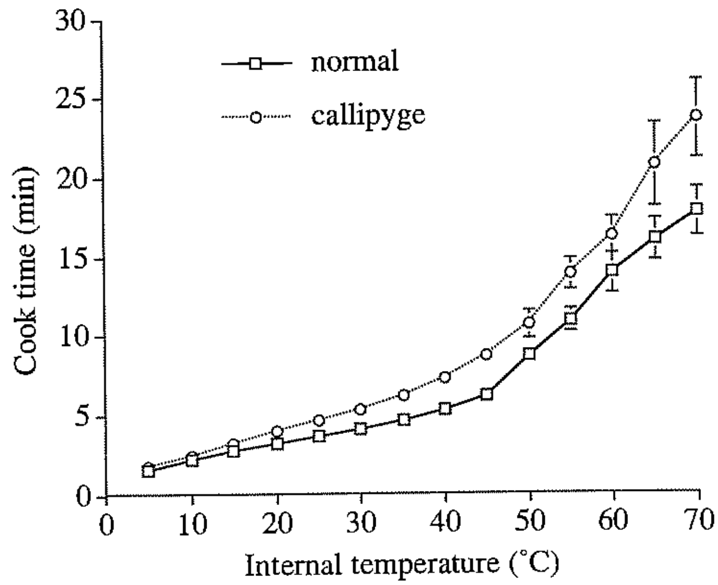
It is also interesting to speculate that the relative toughness of callipyge longissimus is related to the concentration and thermochemical characteristics of its myofibrillar proteins. Compared with normal longissimus, callipyge longissimus has a higher concentration of protein and a considerably greater proportion of fast-twitch fibers (Koohmaraie et al., 1995; Carpenter et al., 1996). More protein and less fat may increase shear values as a consequence of a more compact muscle structure (Lee and Kim, 1994), while the proteins from white (fast-twitch) muscles form stronger gels upon heating than do the proteins from red muscles (Boyer et al., 1995; Egalandsdal and Martinson, 1995). Additionally, shear values could have been influenced by water retention; cooking losses should be measured in future studies.

There was no difference (P = 0.50) in shear values between the cooked leg chops from callipyge and normal animals (Figure 4). This is in contrast to the higher shear values of cooked loin chops from callipyge lambs as compared to those from normal lambs (Figure 1). The reason for this anomaly is not clear, but may be due to muscle type-specific effects and/or method of cookery. Because the leg chops were grilled in a manner similar to the loin chops, our results argue in favor of muscle type-specific effects. Also supporting muscle type-specific effects is the fact that even when roasted, loin chops from callipyge lambs have higher shear values than chops from normal lambs (Field et al., 1996). Still, there is evidence that method of cooking has an effect. Leg roasts from callipyge lambs have similar sensory tenderness as leg roasts from normal lambs, while broiled leg chops from callipyge lamb have slightly decreased tenderness as compared to leg chops from normal lambs (Shackelford et al., 1997).

In contrast to the toughening effect of cooking on the loin chops (Figure 1), cooking decreased (P = 0.02) the shear values of the leg chops (Figure 4). Because cooking hardens the myofibrillar proteins but softens connective tissue (Kropf and Bowers, 1992), this suggests that myofibrillar proteins were the primary determinant of tenderness in the loin chops but that connective tissue was the primary determinant of tenderness in the leg chops. Thus, in the leg chops, any toughening of the myofibrillar proteins was likely overshadowed by the softening of the connective tissue, and it is not surprising that callipyge-related toughness was not evident.

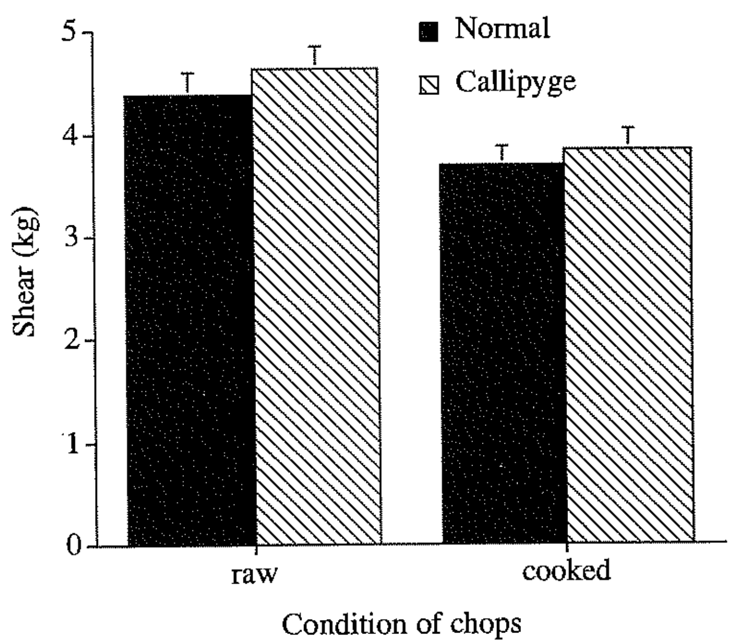
The mean shear values reported here for cooked loin chops from callipyge and normal lambs (3.5 vs. 2.9 kg, respectively) were comparable to our previously-reported values (4.8 vs. 2.3

Figure 3. Cooking time of lamb loin chops.[a]



[a] Callipyge chops required longer (P < 0.01) times to reach the same internal temperatures as normal chops. Error bars equal ± SEM (n = 9 callipyge lambs; n = 10 normal lambs).

Figure 4. Mean shear values of raw and cooked lamb leg chops.[a]



[a] Cooked chops had lower (P = 0.02) shear values than the raw chops, while shear values were similar (P = 0.50) for the cooked chops from callipyge and normal lambs. Error bars equal SEM (n = 9 callipyge lambs; n = 10 normal lambs).

after 15 days aging; Carpenter et al., 1997) and not exceptionally different than the shear values reported by Clare et al. (1997; 3.0 vs. 2.8 after 14 days aging) and Field et al. (1996; 4.4 vs. 2.9 after 14 days aging). However, shear values greatly different than all others are reported by Koohmaraie et al. (1995; 10.1 vs. 4.7 after 7 days aging and 8.2 vs. 3.3 after 21 days aging) and Shackelford et al. (1997; 10.1 vs. 4.4 after 7 days aging). One notable difference between studies is that the animals used by both Koohmaraie et al. and Shackelford et al. were Dorset lambs, while lambs used in the other studies were of various crosses. The mutation responsible for the callipyge phenotype originated in the Dorset breed (Cockett et al., 1996). There are also differences between studies in cooking methods, in final internal temperatures and in sex of the animals, but these differences do not appear to explain the great difference in shear values.

Conclusions

Results of this research suggest that the basal cause of toughness in callipyge lamb loin chops is likely due, at least in part, to the toughening effect of longer cooking times on the myofibrillar proteins. This effect was not observed in chops from the leg, probably because tenderness in these muscles is primarily determined by their connective tissue rather than by their myofibrillar proteins. The longer cooking times and lower fat content of callipyge meat indicate that careful selection of end point temperatures and cooking methods will be critical to ensuring palatable callipyge loin chops.

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Growth and Body Composition of Two Crossbred Wether Types Fed Different Quality Grasses[1,2]

A.L. Goetsch[3,4], S.W. Coleman[5] and W.A. Phillips[5]

Summary

Sixteen crossbred wether lambs were used in a 47-day experiment to determine if effects on growth and body composition of growing wethers of diets based on different quality grasses (LQ = mature switchgrass, with 0.15% body weight of soybean meal; HQ = early head emergence endophyte-free fescue) varied with biological type (D = Dorset × St. Croix-Romanov; S = Suffolk × Dorset-Rambouillet or Polypay). The LQ and HQ forages were 6 and 14% crude protein, 74 and 60% neutral detergent fiber and 5.5 and 2.9% acid detergent lignin, respectively. Initially, D and S wethers averaged 18.8 and 24.8 kg empty body weight, 19.1 and 16.5% empty body protein and 11.3 and 22.5% empty body fat, respectively. On days 21 through 24, digestible organic matter intake was greater ($P = 0.07$) for S versus D and for HQ versus LQ (214, 470, 298 and 487 g/day for D-LQ, D-HQ, S-LQ and S-HQ, respectively) and nitrogen intake was greater ($P < 0.01$) for HQ than for LQ (7.0, 19.3, 9.6 and 19.7 g/day for D-LQ, D-HQ, S-LQ and S-HQ, respectively). Growth measures were not affected ($P > 0.10$) by breed group or the breed × diet interaction; however, empty body weight gain (1, 92, 21 and 105 g/day for D-LQ, D-HQ, S-LQ and S-HQ, respectively), protein accretion (0.96, 7.74, 0.96 and 6.98 g/day for D-LQ, D-HQ, S-LQ and S-HQ, respectively) and fat deposition (-3.8, 50.6, 15.7 and 67.5 g/day for D-LQ, D-HQ, S-LQ and S-HQ, respectively) were greater ($P < 0.01$) for HQ versus LQ. In conclusion, low- to moderate-quality forages during a growing phase may restrict differences in growth and body composition among biological types of crossbred wethers; quality differences between such forages may impact growth and composition similarly regardless of moderate variations in growth potential, mature size or initial body composition.

Key words: sheep, wether, forage quality, growth.

Introduction

Most efficient ruminant production systems occur when animals are well adapted to the environment. Primary factors influencing compatibility are animal genotype and diet quality. Ruminant breeds or biological types possessing high potential for milk production or growth expend more energy for maintenance than animals with lower potential; high production potential is fully expressed only with nonstressful nutritional environments or high-quality diets (Ferrell and Jenkins, 1985; Frisch and Vercoe, 1991; NRC, 1996). Maintenance energy requirements of growing ruminants are typically assumed to differ among biological types with requirements when mature, although this has not been extensively studied.

Besides effects on splanchnic heat production relative to absorbed energy (Goetsch and Patil, 1997), forages varying in quality or digestibility elicit absorption of different quantities of various digestion endproducts (Minson, 1990). Quantities and arrays of absorbed digestion endproducts influence heat production associated with nutrient metabolism and also may interact with potentials for protein and fat accretion

[1] Appreciation is expressed to J.F. Cherry and Dr. D. Von Tungeln for assistance.

[2] Mention of a trademark or proprietary product in this paper does not constitute a guarantee or warranty of the product by the USDA or the ARS and does not imply its approval to the exclusion of other products that also may be suitable.

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which can impact feed intake, composition of gain and/or efficiency of feed usage (Ketelaars and Tolkamp, 1992; Leng et al., 1993).

Increased knowledge of differences among biological types of growing ruminants in efficiency of utilization of different quality forages and diets should facilitate improved matching of animal and feed resources. Therefore, this study was conducted to determine if effects on growth and body composition of crossbred growing wethers of diets based on different quality grasses during a growing phase were similar for different biological types.

Materials and Methods

Sixteen wether lambs were used in a 47-day experiment, being cared for in accordance with guidelines of the Consortium (1988). The experiment was conducted at the Dale Bumpers Small Farms Research Center in Booneville, AR. Eight wethers were reared at the Dale Bumpers Small Farms Research Center and eight were raised at the Grazinglands Research Laboratory in El Reno, OK. Booneville wethers (designated as D; i.e., moderate frame size and growth potential) were from Dorset sires and St. Croix × Romanov ewes; wethers at El Reno (designated as S; i.e., larger frame size and greater growth potential) were from Suffolk sires and Dorset × Rambouillet or Polypay-cross ewes. During the suckling period, wethers grazed grass pasture with access to a supplemental grain-based concentrate mixture. All wethers were treated for *Clostridial* diseases at weaning, at approximately 65 and 75 days for D and S, respectively; treatments for internal parasites were at weaning and at the beginning of the experiment. The D wethers were approximately 4 months old when the trial began in mid-June of 1996 and S wethers averaged 1 week younger.

Wethers were fitted with indwelling catheters in portal, hepatic and mesenteric veins and a mesenteric artery 3 to 4 weeks before the experiment began (Ferrell et al., 1992). During the experiment, wethers were housed indoors and individually in 1.2 m^2 elevated pens with an expanded metal floor. Wethers were allotted to two dietary treatments based on wether type and initial full body weight (BW), for similar mean BW and variation in BW among wether type-diet combinations. Two S wethers on each diet were from Dorset × Rambouillet ewes and two were from Polypay-cross ewes. Diets consisted of ad libitum consumption (offered at 105 to 110% of consumption of the preceding few days) of mature switchgrass (*Panicum virgatum* L.; LQ), plus 0.15% BW (dry matter) of soybean meal or endophyte-free fescue hay cut at early head emergence (*Festuca arundinacea* Schreb.; HQ). Soybean meal was fed with LQ to preclude or minimize ruminal deficiencies of nitrogenous compounds. Hay sources were ground to pass a 1.9-cm screen; water was available free-choice from nipple waterers. Eight grams daily of a mineral mixture (contained at least 12.5% Ca, 12% P, 18% NaCl, 0.8% Zn, 0.7% Fe, 0.5% Mn, 0.02% I, 0.005% Co, 0.00015% Se, 2.2 million IU Vitamin A/kg, 0.45 million IU Vitamin D_3/kg and 275 IU Vitamin E/kg; air-dry basis) was top-dressed at the morning meal. Equal-sized meals were at 0700 and 1900 hours, feed refusals were removed and weighed before the 0700-hour meal and soybean meal was completely consumed.

To determine *in vivo* digestibilities, on days 21 through 24 (4-day period) fecal samples were collected at 12-hour intervals advancing 3 hours daily. Composite fecal samples were formed for each animal on a wet-weight basis and dried at 55 °C; feedstuffs were sampled daily to form weekly composites. Feedstuff and fecal composite samples were ground to pass a 1-mm screen and analyzed for DM, ash, Kjeldahl nitrogen (AOAC, 1984), neutral detergent fiber (filter bag technique; ANKOM Technology Corporation, Fairport, NY) and acid insoluble ash (2 *N* HCl; Van Keulen and Young, 1977). In addition, hay was analyzed for acid detergent fiber and lignin (filter bag technique); cellulose was determined as loss in weight upon sulfuric acid treatment and hemicellulose as the difference between neutral and acid detergent fiber concentrations. Soybean meal was analyzed for DM, ash, nitrogen, neutral detergent fiber and acid insoluble ash. Acid insoluble ash was used as in inert, internal marker for estimation of digestion. Feed intake was calculated for the entire experiment and for the 2 days before and the 4 days of fecal sampling (6 days total).

Wethers were weighed full at the beginning and end of the experiment. After each weighing, feed and water were withheld for 24 hours. Body composition was determined via urea dilution as described by Galloway et al. (1996) although the urea solution was infused (162.5 mg/kg BW) into, and blood was withdrawn from, the hepatic vein catheter of all wethers. In short, empty BW (EBW) was estimated by weighing immediately after sampling. Urea space (US) was calculated as urea infused/change in serum concentration before infusion and at 12 minutes after infusion. A sample at 21 minutes was also taken to allow correction via linear regression of the 12-minute sample urea concentration to exactly 12 minutes, if the midpoint of sampling was not exactly at 12 minutes. Water and fat in the empty body (EBH_2O and EBFAT, respectively) were calculated with regressions presented by Poland (1991). The equation for kg EBH_2O was 7.86 + (0.259 EBW in kg) + (0.195 US in kg). The equation for kg EBFAT was -8.92 + (0.625 EBW in kg) - (0.275 US in kg). Percentages of protein and ash in the empty body (%EBPRO and %EBASH, respectively) were estimated as described by Reid et al. (1968). The equation for %EBPRO was %EBH_2O × 0.27173, and that for %EBASH was %EBH_2O × 0.06356. To determine energy accretion, 5.52 and 9.4 kcal/g of protein and fat, respectively, were assumed (ARC, 1980).

Data were analyzed by General Linear Models procedures of SAS (1990). Initial body composition variables were analyzed with a model consisting of breed. For all other data, a model (2 × 2 factorial) consisting of breed group, dietary treatment and the breed × diet interaction was used.

Results and Discussion

Results

Concentrations of neutral detergent fiber, acid detergent lignin and crude protein reflect differences between grass sources in species and maturity level at harvest (Table 1). Full and empty initial BW were greater ($P < 0.01$) for S than for D wethers (Table 2). Percentages of water, protein and ash in the initial empty body were lower ($P < 0.01$) for S versus D but quantities were slightly greater ($P < 0.01$) for S. The percentage of fat in the initial empty body was more than 10 percentage units greater ($P < 0.01$) for S than for D and fat mass for S was more than twice that for D ($P < 0.01$).

No interactions between breed group and diet were noted for any measure ($P > 0.10$). Hay and total DM intakes during the fecal collection period were greater for S versus D wethers ($P = 0.09$) and for HQ versus LQ forage ($P < 0.01$; Table 3). Differences between breeds and diets in total organic matter and neutral detergent fiber intakes corresponded to those in total DM intake and to forage chemical composition; nitrogen intake was greater ($P < 0.01$) for HQ than for LQ. Organic matter, neutral detergent fiber and nitrogen digestibilities were approximately 10 percentage units greater ($P < 0.01$) for HQ versus LQ. Digestible organic matter, neutral detergent fiber and nitrogen intakes were greater ($P < 0.01$) for HQ versus LQ and digestible organic matter and neutral detergent fiber intakes were greater ($P = 0.07$ and 0.05, respectively) for S than for D wethers.

Average DM intake for the entire experiment (Table 4) was fairly similar to that during the fecal collection period, although breed effects on hay and total DM intakes ($P = 0.03$) were of slightly greater magnitude. Live and empty BW gains and the ratio of BW gain to DM intake were greater ($P < 0.01$) for LQ than for HQ, although differences between wethers types were nonsignificant ($P > 0.10$). Percentages of water, protein and ash were lower for S versus D and for HQ versus LQ ($P = 0.04$) and water, protein and ash masses were greater ($P < 0.01$) for S versus D. Effects of breed ($P = 0.01$) on the percentage and mass of fat in the empty body were relatively greater than those of diet ($P = 0.04$ and 0.08, respectively). Daily rates of accretion of fat, protein and total energy were greater ($P < 0.01$) for HQ versus LQ and were not affected by breed or the breed × diet interaction ($P > 0.10$).

Discussion

Diet. Slower ruminal microbial digestion and digesta outflow for LQ than for HQ may have resulted in a lower level of intake at which maximal ruminal digesta capacity or fill was attained (Mertens, 1994). If so, then ruminal digesta capacity relative to BW was similar between breed groups. However, it seems equally plausible that forage intake was regulated metabolically or physiologically (e.g., Ketelaars and Tolkamp, 1992; Tolkamp and Ketelaars, 1992; Leng et al., 1993).

A greater ratio of splanchnic bed heat production to absorbed energy with LQ than HQ was expected because of differences in factors such as gut digesta mass or physical or chemical properties (Goetsch and Patil, 1997). Assuming relatively constant whole body efficiency of energy metabolism with ad libitum intake and practical production conditions (Tolkamp and Ketelaars, 1994), ad libitum feed intake may be that at which efficiencies of energy metabolism in the splanchnic bed and extra-splanchnic tissues sum to constant whole body efficiency or heat production relative to metabolic BW or surface area (Goetsch and Patil, 1997). Thus, high heat production by the splanchnic bed

Table 1. Feedstuff composition.[a]

Item	Switch-grass hay	Endophyte-free fescue hay	Soybean meal
Ash	6.8	10.3	9.2
Crude protein	6.0	14.0	59.7
Neutral detergent fiber	73.9	60.3	15.0
Acid detergent fiber	43.8	33.7	–
Acid detergent lignin	5.5	2.9	–
Cellulose	37.3	29.7	–
Hemicellulose	30.1	26.6	–

[a] % of dry matter.

Table 2. Initial body weight and composition for two wether types.

Item	Wether type D[a]	Wether type S[b]	SE[c]
Body weight, kg:			
Full	21.0[d]	26.8[e]	1.09
Empty	18.8[d]	24.8[e]	0.99
Empty body composition:			
Water, %	70.4[e]	60.6[d]	1.52
Water, kg	13.2[d]	14.9[e]	0.30
Protein, %	19.1[e]	16.5[d]	0.41
Protein, kg	3.58[d]	4.04[e]	0.081
Ash, %	4.48[e]	3.85[d]	0.096
Ash, kg	0.84[d]	0.94[e]	0.019
Fat, %	11.3[d]	22.5[e]	1.71
Fat, kg	2.19[d]	5.77[e]	0.568

[a] D = moderate frame size and potential growth rate (Dorset × St. Croix-Romanov).

[b] S = larger frame size and more rapid potential growth rate (Suffolk × Dorset-Rambouillet or Polypay cross); eight wethers per wether type.

[c] SE = standard error.

[d,e] Means in a row without a common superscript differ ($P < 0.01$).

relative to absorbed energy, as for LQ, could limit feed intake and tissue accretion by restricting the quantity of energy metabolized and heat produced by extra-splanchnic tissues at which maximum whole body heat generation relative to metabolizable energy intake occurs.

Although HQ was 14% crude protein and soybean meal supplemented LQ, protein deposition with both diets may have been limited by amino acid availabilities. Ratios of crude protein intake to digestible energy intake for LQ were quite similar to that required for maximal growth by 30-kg finishing lambs (NRC, 1985), although absolute intakes were considerably lower. For HQ, ratios of crude protein intake to digestible energy intake were slightly greater than required for 30-kg wethers with differences between intake and the requirement slightly greater for digestible energy than for crude protein. However, extensive ruminal microbial degradation of forage protein could have resulted in a relatively greater limitation for protein synthesis of amino acid than energy availability. Thus, intestinal amino acid absorption may have affected potential for expression of a difference between wether types in rate of protein accretion.

Breed and Diet × Breed. Similar BW gains and protein and fat accretion rates for D and S wethers might have resulted, in part, from neither breed group being extreme in characteristics such as mature size or growth potential. Also, diets based on forage – particularly when low in quality – restrict peripheral tissue energy availability because of high splanchnic energy use relative to that absorbed compared with diets containing concentrate, thereby perhaps minimizing opportunity for expression of differences in peripheral tissue growth potential. A difference between wether groups in capacity for energy accretion might have been expressed with greater digestible organic matter intake, such as with dietary cereal grain inclusion. For example, in a recent experiment (our unpublished observations) a growing phase diet with corn offered at 2.5 versus 1.0% of BW increased fat and protein mass of Suffolk × St. Croix lambs significantly more than for Romanov × St. Croix lambs. This interaction may have occurred because energy and nutrient intakes exceeded capacity for energy accretion by Romanov × St. Croix lambs but not by Suffolk × St. Croix lambs. Goetsch (1998) noted lower BW gain by suckling Suffolk × St. Croix versus Romanov × St. Croix lambs, without creep feed consumption and while ewes consumed a moderate- to low-quality grass hay. This difference could have resulted from conduct of the experiment before growth curves of the two biological types diverged

Table 3. Feed intake and digestion for two wether types consuming different quality grass hays during growing.[a]

	Wether type						
	D[b]		S[c]			Effect (P ≤)[d]	
Item	LQ[e]	HQ[f]	LQ[e]	HQ[f]	SE[g]	Breed	Diet
Dry matter intake, g/day:							
Soybean meal	29	0	41	0	1.5	0.01	0.01
Hay	434	860	590	876	51.0	–	0.01
Total	463	860	631	876	51.0	0.09	0.01
Organic matter:							
Intake, g/day	431	771	587	786	45.9	0.09	0.01
Apparent digestion, %	49.6	61.3	50.8	62.0	1.08	–	0.01
Apparent digestion, g/day	214	470	298	487	26.0	0.07	0.01
Neutral detergent fiber:							
Intake, g/day	325	518	442	528	31.5	0.07	0.01
Digestion, %	46.1	57.5	47.4	58.1	1.55	–	0.01
Digestion, g/day	150	296	210	307	16.1	0.05	0.01
Nitrogen:							
Intake, g/day	7.0	19.3	9.6	19.7	1.11	–	0.01
Apparent digestion, %	54.3	63.3	54.0	64.8	1.12	–	0.01
Apparent digestion, g/day	3.8	12.2	5.2	12.8	0.69	–	0.01

[a] Days 21 to 24 of the 47-day experiment; four wethers per treatment.
[b] D = moderate frame size and potential growth rate (Dorset × St. Croix-Romanov)
[c] S = larger frame size and more rapid potential growth rate (Suffolk × Dorset-Rambouillet or Polypay cross).
[d] P-value listed if ≤ 0.10.
[e] LQ = mature switchgrass.
[f] HQ = endophyte-free fescue, early head emergence.
[g] SE = standard error.

and because energy and amino acid absorption was inadequate to meet the presumably greater maintenance demands of Suffolk × St. Croix lambs. Overall, a comparison of results of these studies suggests that diet quality or energy intake in the present experiment was adequate to prevent expression in BW gain of a potential difference between wether groups in maintenance energy requirement but insufficient to allow display of greater growth potential of S wethers.

Conclusions

Growing phase diets based on low- to moderate-quality grasses, differing in digestibility, may similarly affect growth and body composition of different biological types of crossbred wethers as used in this study.

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Table 4. Feed intake, performance, body composition and tissue accretion for two wether types consuming different quality grass hays during growing.[a]

	Wether type						
	D[b]		S[c]			Effect (P ≤)[d]	
Item	LQ[e]	HQ[f]	LQ	HQ	SE[g]	Breed	Diet
Dry matter intake, g/day:							
Soybean meal	29	0	41	0	1.5	0.01	0.01
Hay	426	832	582	910	49.0	0.03	0.01
Total	455	832	623	910	49.3	0.03	0.01
Average daily gain, g/day:							
Live weight	-7	87	23	112	23.3	–	0.01
EBW[h]	1	92	21	105	21.5	–	0.01
Live weight gain:DM[i] intake:	-0.018	0.099	0.036	0.126	0.0282	–	0.01
Final composition:							
Water, % of EBW	70.4	63.7	56.7	55.8	1.68	0.01	0.04
Water, kg	13.4	14.4	15.6	15.5	0.32	0.02	–
Protein, % of EBW	19.1	17.3	15.4	15.2	0.46	0.01	0.04
Protein, kg	3.64	3.92	4.23	4.21	0.087	0.01	–
Ash, % of EBW	4.47	4.05	3.60	3.55	0.107	0.01	0.04
Ash, kg	0.851	0.916	0.990	0.985	0.0204	0.01	–
Fat, % of EBW	11.2	18.8	27.0	28.1	1.96	0.01	0.04
Fat, kg	2.19	4.38	7.48	7.88	0.674	0.01	0.08
Accretion:							
Protein, g/day	0.96	7.74	0.96	6.98	1.364	–	0.01
Fat, g/day	-3.8	50.6	15.7	67.5	14.90	–	0.01
Energy, Mcal/day	-0.030	0.518	0.153	0.673	0.1466	–	0.01

[a] Four wethers per treatment.
[b] D = moderate frame size and potential growth rate (Dorset × St. Croix-Romanov).
[c] S = larger frame size and more rapid potential growth rate (Suffolk × Dorset-Rambouillet or Polypay cross).
[d] P value listed if ≤ 0.10.
[e] LQ = mature switchgrass.
[f] HQ = endophyte-free fescue, early head emergence.
[g] SE = standard error.
[h] EBW = empty body weight.
[i] DM = dry matter.

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Comparison of Crossbred Boer × Spanish and Purebred Spanish Breed-types for Kid Growth and Litter Size Traits[1,2]

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Summary

Our objective was to compare purebred Spanish (S) and 1/4 Boer (B) × 3/4 Spanish crossbred (B×S) kids for growth traits under south Texas conditions. Spanish does were pen-mated to either a S or a B×S buck. Traits studied were litter size born (LSB), birth weight (BW), 90-day weaning weight (WW), preweaning average daily gain (ADG) and preweaning survival. Records on 69 kids born in 1996 to 46 dams and 6 sires were analyzed. Model effects included fixed breed-type, parity of doe (primi- vs. multiparous), LSB (single vs. multiple; growth traits only), gender of kid (growth traits only), all two-way interactions, and random sire within breed-type and litter within sire by breed-type (growth traits only) and error. The S and B×S kids had similar BW (2.82 and 3.10 kg; $P > 0.05$), but the B×S had heavier WW (13.6 and 15.8 kg; $P < 0.05$) and had greater ADG by 23 g/day compared to S kids ($P < 0.05$). The doe parity difference was not important for LSB ($P > 0.05$). As expected, single-born kids had significantly heavier BW and WW and greater ADG compared to multiple-born kids. Neither doe parity nor kid gender influenced growth traits ($P > 0.05$); however, a significant doe parity by kid gender interaction was detected for WW and ADG (male but not female kids had better performance when reared by mature as opposed to yearling dams). Overall, experiment results indicate that the Boer breed improved WW and ADG traits in crossbred kids.

Key words: goats, growth, litter size, crossbreeding, Boer.

Introduction

Since the first introduction of the Boer breed of goat into the United States in 1993 there has been considerable interest in the potential impact of this improved breed on the meat goat industry. In its native South African environment, the Boer goat is noted for rapid growth (Naude and Hofmeyr, 1981) and heavy and lean carcasses (Van Niekerk and Casey, 1988). In addition, Boer goats are reported to be good browsers, have resistance to parasites, be seasonally polyestrous breeders and to produce large litters when intensively managed (Skinner, 1972; Barry and Godke, 1991). Hence, investigations evaluating the genetic potential of the Boer through crossbreeding with available U.S. breeds (e.g., Spanish, Angora, Nubian) would be well justified. Blackburn (1995) reported specific research needs for evaluating Boer goat reproductive rate, herd productivity, biological efficiency and response to stressful conditions under a wide range of environments. To date, there is a paucity of reported information available from actual or simulated production studies in the U.S. (Blackburn, 1995; Waldron et al., 1995, 1997; Lewis et al., 1997).

It is plausible that traditional limited-resource producers who maintain Spanish stock might justify the use of crossbred as opposed to purebred Boer bucks to initiate either simple upgrading or possibly terminal crossbreeding systems. Therefore, our main

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experimental objective was to compare purebred Spanish with 1/4 Boer crossbred kids for growth traits, and also Spanish does for litter size born when producing Spanish or crossbred kids, in south Texas. In addition, effects of doe parity, litter size at birth, gender of kid and interactions on doe and kid performance were examined.

Materials and Methods

The experimental goat herd was maintained on improved pastures at the Research and Teaching Farm of Texas A&M University-Kingsville. Three weeks prior to the breeding season, 57 adult Spanish does (> 6 months old) were flushed with 227 g of corn per head daily to stimulate multiple ovulation. They also had access to commercial mineral blocks (COOP Block Stock-39; Farmland Industries, Inc., Kansas City, MO). The goat herd was treated for internal parasites on a bimonthly basis.

One Spanish buck (S) was obtained from each of the following sources: a local breeder (Kingsville, TX), La Copita Agricultural Experimental Station (Alice, TX) and Texas Agricultural Research and Extension Center (San Angelo, TX). Our sample of S bucks was considered to be characteristic of the breed. Three 1/2 Boer × 1/2 Spanish (B×S) crossbred bucks, one from a hill country breeder (Garden City, TX) and two from Texas Agricultural Research and Extension Center (San Angelo, TX) were also acquired. These crossbred bucks were selected at random for our study. Crossbred bucks were not closely related.

In October of 1995, does were randomly assigned by parity (primi- vs. multiparous groups) to one of six breeding pens (area of 33 m^2) and were exposed for 6 weeks to either a S or a B×S buck. During this period, stock were fed Bermuda grass hay (*Cynodon* spp.) supplemented with corn, and minerals from blocks. Afterwards, does were returned as a single group to open pastures. Three months after service, pregnancy was confirmed using an Aloka 500 V scanner equipped with a 5.0 mHz probe (Corometrics Medical Systems, Inc., Wallingford, CN). Following pregnancy confirmation, all does were fed 227 g of corn per head per day as a supplement to forage from pasture until parturition.

The kidding season was from March to April of 1996. Within 24 hours of parturition, litter size and gender were recorded, kids were weighed and ear-tagged for identification and male kids were castrated. When kids were 3 days old, does and kids were returned to pasture and does were supplemented with corn (227 g/head) and minerals from blocks. Preweaning survival was monitored from birth to 90 days of age when kids were weaned and weighed. Traits investigated were litter size born (LSB), birth and weaning weights (BW and WW), 1 to 90 days preweaning average daily gain (ADG; calculated from individual BW and WW) and preweaning survival from birth.

Data were analyzed using the GLMM software package by Blouin and Saxton (1990). The statistical model used for growth traits included fixed effects for breed-type (S or B×S), parity of doe (1 or ≥ 2), litter size born (1 or ≥ 2), gender of kid (male or female), all two-way interactions between fixed effects and random effects for sire nested within breed-type, litter nested within sire and breed-type and error. The sire mean square was used to test the significance of the breed-type effect, whereas the litter mean square was used to test all other effects except those that pertained to gender. The statistical model for LSB consisted of breed-type, sire within breed-type, parity of doe, breed-type by parity interaction and error. Final models excluded non-significant interaction terms ($P > 0.05$).

Results and Discussion

Reproduction Success

A total of 69 kids (S = 38, B×S = 31) were born to 46 litters with no known cases of stillbirths. Overall fertility was 81% and prolificacy was 1.21 kids born per doe exposed, or 1.50 kids born per doe kidding. The relatively low fertility level may have reflected previous drought conditions. Lawson and Shelton (1982) and Bogui (1986) reported averages of 1.32 and 1.70 kids born per doe kidding in Spanish does, respectively. All does had either single or twin births, except one S doe kidded a set of purebred quintuplets (three of which died < 1 week after birth). Because no mortality occurred in single- and twin-born sets, it was

Table 1. Generalized least-squares means for litter size at birth and kid growth traits according to breed-type.

		Trait			
Breed-type	Kids, number	LSB[a]	BW[b]	WW[c]	ADG[d]
Spanish	38	1.46 ± 0.1	2.82 ± 0.1	13.6 ± 0.4[f]	119 ± 5[f]
Boer × Spanish[e]	31	1.40 ± 0.1	3.10 ± 0.1	15.8 ± 0.5[g]	141 ± 5[g]

[a] LSB = litter size at birth.
[b] BW = birth weight, kg.
[c] WW = weaning weight (90 days), kg.
[d] ADG = preweaning average daily gain (1 to 90 days), g.
[e] Crossbred group was 1/4 Boer × 3/4 Spanish produced by mating 1/2 Boer × Spanish crossbred bucks to Spanish purebred does.
[f,g] Means within a column with different letters in their superscripts differ at $P < 0.05$.

not necessary to analyze preweaning survival. Therefore, all kids were reared as either singles or twins.

Breed-type Results

Breed-type did not significantly affect LSB. Least-squares means for LSB for S and B×S were 1.46 and 1.40 kids, respectively (Table 1). The influence of breed-type of service sire on rate of fertilization and/or embryonic survival appeared to have been minimal. The mean birth dates between kids of both breed-types were similar. In contrast, Burfening and Davis (1996) reported in sheep that individual service sire had a large effect on number of lambs born per ewe lambing, although specific causes were unknown.

The difference of 0.28 kg (10%) in BW between S and B×S kids was not significant. Waldron et al. (1995) reported heavier BW of only 0.26 kg for B×S (B♂ × S♀) compared to S kids (six sires of each breed-type were used in their study). Their sample of S bucks was representative of the more outstanding bucks of the breed such that smaller breed-type differences may have resulted. Also, their experiment was conducted in west Texas where a severe drought resulted in poor range conditions which may have limited genetic expressions between breed-types. Belay et al. (1992) reported heavier BW for crossbred (B♂ × Small East African♀ [SEA] and Kamorai♂ × SEA♀) by only 0.11 and 0.14 kg compared to purebred SEA kids, respectively. In Kenya, Haas (1978) likewise observed Boer crosses to have heavier BW than SEA purebred kids.

The B×S kids had heavier WW than S kids (means of 15.8 and 13.6 kg; $P < 0.05$). Theoretically, this difference (B×S minus S performance) was attributable to individual breed additive and heterotic contributions. Waldron et al. (1995) found B×S kids to have heavier 90-day WW by only 0.67 kg than S kids. According to APRU (1984), B purebreds and B × Tswana crossbreds had comparable WW (27.4 and 27.3 kg), whereas Tswana purebreds were inferior (25.1 kg).

Preweaning ADG was greater by 23 g/day in B×S compared to S kids ($P < 0.05$). Haas (1978) found Boer crosses to have greater preweaning ADG than SEA purebred kids (114 versus 84 g/day). Calculated from data presented by Waldron et al. (1995), 1-to-90-day ADG was greater by only 5 g/day in B×S than in S kids.

Parity, Litter Size and Gender Effects

Parity of doe (P) did not significantly influence LSB or any of the growth traits studied, despite the 0.14 difference observed for LSB. The reason for failure to detect significance was probably due to the small sample size. Mean LSB was 1.50 and 1.36 kids for yearling and mature does, respectively. Previous goat studies have demonstrated that fertility or litter size (Epstein and Hertz, 1964; Waldron et al., 1997) and kid body weight (Angwenyi, 1984; Mavrogenis et al., 1984; Ahuya, 1987; Ruvuna et al., 1988; Gebrelul et al., 1994; Sanchez et al., 1994) generally improve with increased doe parity and/or age.

Single-born kids had heavier BW by 0.37 kg, had heavier WW by 2.4 kg and had greater preweaning ADG by 23 g/day than multiple-born kids ($P < 0.01$; Table 2). These results are generally consistent with the goat research literature. Fourie and Venter (1985) observed that the greater availability of milk for single-born compared to multiple-born purebred B kids was the major factor accounting for growth differences.

Gender did not significantly affect growth traits. Generally, goat studies indicate that males are heavier than females from birth to maturity. However, Ramsay and Smit (1987), who evaluated B and Veld indigenous breeds in South Africa, observed greater preweaning ADG in female compared to male kids (123.0 and 92.8 g/day in B kids and 82.1 and 67.2 g/day in Veld kids, respectively).

The only significant interaction was due to parity of doe by gender of kid for WW and ADG (Table 2). Females born to yearling versus mature does had heavier WW (15.3 vs. 14.0 kg) and greater ADG (138 vs. 121 g/day). Conversely, males born to mature versus yearling does had heavier WW (15.4 vs. 14.1 kg) and greater ADG (138 vs. 123 g/day).

Table 2. Generalized least-squares means for kid growth traits according to parity of doe, litter size born and gender.

Item	BW[a]	WW[b]	ADG[c]
Parity of doe (P):			
Yearling	3.0 ± 0.1	14.7 ± 0.4	131 ± 5
Mature	2.9 ± 0.1	14.7 ± 0.5	130 ± 5
Litter size born:			
Single	3.15 ± 0.1[d]	15.9 ± 0.4[d]	142 ± 5[d]
Multiple	2.78 ± 0.1[e]	13.5 ± 0.5[e]	119 ± 5[e]
Gender (G):			
Female	2.89 ± 0.1	14.7 ± 0.4	130 ± 4
Male	3.03 ± 0.1	14.8 ± 0.4	131 ± 4
P × G (significance level)	NS[f]	< 0.05	< 0.05
Yearling dam by female kid	2.90 ± 0.1	15.3 ± 0.5	138 ± 5
Yearling dam by male kid	3.09 ± 0.1	14.1 ± 0.6	123 ± 6
Mature dam by female kid	2.90 ± 0.1	14.0 ± 0.6	121 ± 6
Mature dam by male kid	2.98 ± 0.1	15.4 ± 0.6	138 ± 6

[a] BW = birth weight, kg.

[b] WW = weaning weight (90 days), kg.

[c] ADG = preweaning average daily gain (1 to 90 days), g.

[d,e] Means for the same trait within the LSB factor bearing different superscripts differ ($P < 0.01$).

[f] NS = not significant.

Conclusions

The BXS kids were superior to S kids for WW and ADG but not for BW. The LSB did not appear to be affected by the genotype of fetus. Hence, traditional producers that first utilize crossbred BXS bucks (as opposed to purebred Boer bucks) may be rewarded economically by heavier kid market weights (assuming market price is on a per pound rather than on a per head basis). Results suggest that kid production, as measured by WW and ADG, could be improved by using BXS bucks as an alternative to using S bucks in south Texas goat operations. However, further studies are needed to determine the optimal breed combination for maximum kid production and to evaluate the economic impact of the Boer breed on the U.S. meat goat industry.

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Estrous Synchronization and Pregnancy Rate of Transcervically Inseminated Ewes During the Breeding Season[1,2]

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Summary

Two experiments were conducted during the fall breeding season to evaluate estrous synchronization protocols for use with transcervical artificial insemination (T-AI). In Experiment 1, multiparous Polypay ewes (n = 65) were isolated from rams and received 500 mg progesterone-containing sponges. Sponges were removed 14 days later (0 hour), at which time ewes were (TR; n = 43) or were not (NTR; n = 22) exposed to vasectomized teaser rams. Ewes were T-AI using frozen-thawed semen 51 hours following sponge removal or 20 hours following detected estrus. Blood samples were collected at 3-day intervals for progesterone analysis. In TR and NTR ewes, subsequent luteal progesterone concentrations increased to > 4 or ≤ 3 ng/mL ($P \leq 0.01$), respectively. In Experiment 2, mature Polypay ewes were synchronized by administration of two 20 mg $PGF_{2\alpha}$ injections given 11 days apart ($PGF_{2\alpha}$-$PGF_{2\alpha}$); or by giving one injection of GnRH (100 µg, i.m.), followed 5 days later by 20 mg $PGF_{2\alpha}$ (GnRH-$PGF_{2\alpha}$). T-AI was performed 44 to 52 hours following the last $PGF_{2\alpha}$ injection. Estrus was detected by teaser rams in 12/17 $PGF_{2\alpha}$-$PGF_{2\alpha}$-treated ewes and in 17/18 GnRH-$PGF_{2\alpha}$-treated ewes ($P = 0.06$). Respective intervals to estrus were 38 and 27 hours ($P < 0.05$). Eight $PGF_{2\alpha}$-$PGF_{2\alpha}$-treated ewes and 10 GnRH-$PGF_{2\alpha}$-treated ewes were diagnosed pregnant on day 30 ($P > 0.1$), of which 7 and 9 ewes lambed, respectively. Cervical penetration rates were similar among ewes in the two treatment groups. Results indicate that inclusion of teaser rams into estrous synchronization protocols during the breeding season enhances luteal function. The $PGF_{2\alpha}$-$PGF_{2\alpha}$ and GnRH-$PGF_{2\alpha}$ estrous synchronization methods resulted in similar pregnancy and lambing rates following T-AI. The latter method tended to produce a greater incidence of estrus.

Key words: ewes, estrous synchronization, transcervical artificial insemination.

Introduction

Transcervical artificial insemination (T-AI) has been used in previous studies to allow non-surgical intrauterine deposition of frozen-thawed semen into ewes (Husein et al., 1996 and 1998). Those studies were conducted during seasonal anestrus with the aim of reducing the number of rams needed for synchronized mating. Estrus and ovulation were induced using progesterone-containing sponges and the sudden introduction of rams (Wheaton et al., 1992). Present experiments were conducted to evaluate estrous synchronization protocols for use with T-AI during the breeding season. In Experiment 1, ewes received progesterone-containing sponges and at the time of sponge removal were or were not exposed to vasectomized teaser rams. Experiment 2 compared two estrous synchronization methods that do not require exogenous progesterone. These were the sequential administration of $PGF_{2\alpha}$ (Beck et al., 1987) and the more recently developed protocol in which GnRH and

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$PGF_{2\alpha}$ are given 5 days apart (Beck et al., 1996). The methods were evaluated for incidence of estrus and pregnancy rates following T-AI.

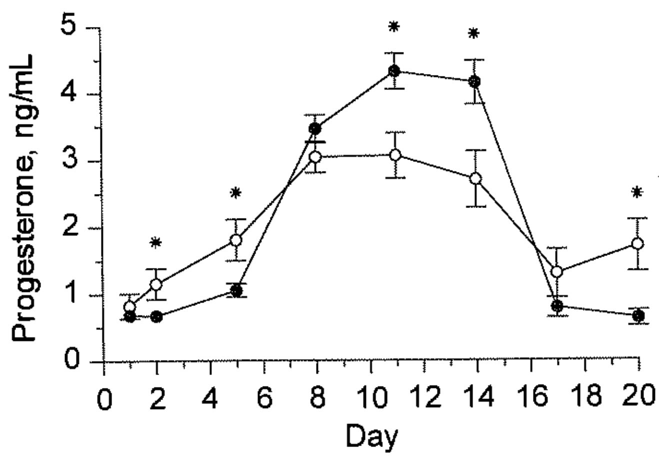
Materials and Methods

Experiment 1

Rams and ewes grazed on adjacent pastures until 65 Polypay 2- to 5-year-old multiparous ewes weighing 77 ± 1 kg were moved to a wing of the sheep unit. Ewes were exposed to ambient photoperiod and temperature through opened-gated doors. Grass hay and corn/soy bean pellets (0.2 kg/ewe) were fed once daily and trace mineral salt was available on an ad libitum basis. Rams were moved to another wing of the sheep unit separated from ewes by walls and a distance of 37 m. Two days later all ewes were administered an intravaginal sponge containing 500 mg progesterone. Sponges were made as described by Husein et al. (1996). Ewes were assigned randomly to two treatment groups: teaser ram (TR; n = 43) or no teaser ram (NTR; n = 22). Sponges were left in place for 14 days and removed on November 27 at 0600 hours (day 0, hour 0), at which time TR ewes were moved to the wing with rams and penned with three vasectomized Columbia rams fitted with marking harnesses. Ewes with breeding marks were observed for standing estrus at 6-hour intervals. Blood samples (3 mL) were drawn by venipuncture from NTR and TR ewes on days 1 and 2 and then at 3-day intervals until day 20. Blood samples were placed into chilled heparinized (15 IU) tubes, centrifuged at 1,500 × g for 20 minutes and plasma stored at -20 °C. Plasma progesterone concentrations were assayed in a single RIA (Hamra et al., 1989). Sensitivity was 0.08 ng/mL and the intraassay CV was 3.7% (Figure 1).

Ewes in the NTR group were T-AI in random order at 10-minute intervals, which averaged 51 hours following sponge removal. Ewes in the TR group were assigned randomly in advance to be T-AI at either 51 hours following sponge removal (n = 21) or 20 hours following detected estrus (n = 22). Three of the latter ewes did not express estrus and were T-AI at 51 hours. Transcervical-AI and semen processing procedures have been described previously (Husein et al., 1996). Semen was collected from two proven Polypay rams during the breeding season. Semen from the ram that gave the highest post-thaw motility (~50%) was selected for use. Ewes were inseminated with ~200 × 10^6 motile frozen-thawed spermatozoa. Pregnancy was determined using transrectal ultrasonography (Aloka 500V console and 7.5 MHZ prostate probe; Corometrics Medical Systems, Inc., Wallingford, CT) on day 30.

Figure 1. Plasma progesterone concentrations in non-pregnant ewes not exposed (○, NTR, n = 21) and exposed (•, TR, n = 41) to teaser rams following pessary removal. Pessaries were removed on day 0.[a]



[a] ✱ = P < 0.01.

Experiment 2

Thirty-five 3- to 6-year-old Polypay ewes weighing 72 ± 1 kg with a body condition score of ≥ 2.5 on a 0-to-5 low-to-high scale were used during the breeding season at the University of Minnesota West Central Experiment Station (46° N). Ewes were maintained in a single pen (12 m × 5 m) in a shed and fed 1.8 kg alfalfa hay and 0.45 kg whole corn per ewe/day and selenium-fortified salt and water were available free choice. Ewes were assigned randomly to two treatment groups: $PGF_{2\alpha}$-$PGF_{2\alpha}$ (n = 17) and GnRH-$PGF_{2\alpha}$ (n = 18). Ewes in the $PGF_{2\alpha}$-$PGF_{2\alpha}$ group received two i.m. injections of 20 mg $PGF_{2\alpha}$ (Lutalyse; The Upjohn Company, Kalamazoo, MI) administered 11 days apart. Ewes in the GnRH-$PGF_{2\alpha}$ group received 100 µg GnRH (Cystorelin; Rhone Merieux, Athens, GA) i.m. followed 5 days later by 20 mg $PGF_{2\alpha}$. The final $PGF_{2\alpha}$ injection in both treatment groups was given on November 12 at 1200 hours (day 0, hour 0). At 0000 hours ewes were exposed to three vasectomized rams fitted with marking harnesses and ewes were checked for breeding marks at 6-hour intervals for 72 hours. Ewes observed in standing estrus were moved to an adjacent pen. Ewes were inseminated in random order from 44 to 52 hours following the last $PGF_{2\alpha}$ injection. Ewes in which full cervical penetration was not felt to have occurred were inseminated at the depth reached. Transcervical-AI and pregnancy diagnosis were performed as described for Experiment 1, except that semen had been collected from Targhee rams.

Data were analyzed using SAS/STAT GLM and ANOVA procedures (SAS/STAT, 1990). Plasma progesterone concentrations from days 1 to 20 were analyzed for effect of teaser ram using repeated measures ANOVA. Treatment effects on incidence of estrus, pregnancy and lambing rates and cervical penetration rate were analyzed using Chi-square. Treatment differences in various intervals, cervical penetration time and number of lambs born were tested using Student's t-test. Continuous data from pregnant and non-pregnant ewes were compared retrospectively using Student's t-test and categorical data were compared using Chi-square.

Results and Discussion

Results

Experiment 1. Estrus was detected in 34/43 TR ewes and intervals from sponge removal to detected estrus averaged 15 ± 2 hours and ranged from 6 to 36 hours. Progesterone concentrations were greater ($P < 0.01$) in NTR than TR ewes on days 2, 5 and 20 and lower ($P < 0.01$) on days 11 and 14 (Figure 1; treatment-by-day interaction, $P < 0.001$). Complete cervical penetration was considered to have occurred in 64/65 ewes and averaged 4.1 ± 0.3 minutes. On day 30 pregnancy was diagnosed in three (5%) ewes (1/22 NTR and 2/43 TR ewes). Progesterone concentrations in these ewes remained > 3 ng/mL from days 11 to 20.

Experiment 2. Incidence of estrus tended ($P = 0.06$) to be greater in GnRH-$PGF_{2\alpha}$-treated than $PGF_{2\alpha}$-$PGF_{2\alpha}$-treated ewes within 3 days following the last $PGF_{2\alpha}$ injection (Table 1). Intervals from the last $PGF_{2\alpha}$ injection to detected estrus were shorter ($P < 0.05$) in GnRH-$PGF_{2\alpha}$-treated than $PGF_{2\alpha}$-$PGF_{2\alpha}$-treated ewes and ranged from 6 to 42 hours in the former and from 24 to 72 hours in the latter. Ewes were T-AI 47.7 ± 0.4 hours following the last $PGF_{2\alpha}$ injection. Complete cervical penetration was considered to have occurred in 30/35 ewes and time needed for manipulation of the probe through the cervical canal averaged 5.8 ± 0.5 minutes. Neither item was influenced by method of estrous synchronization. Pregnancy rate using T-AI was 51% (18/35) and was similar in $PGF_{2\alpha}$-$PGF_{2\alpha}$ (47%) and GnRH-$PGF_{2\alpha}$ (56%) ewes (Table 1). Of ewes diagnosed pregnant, 9/10 GnRH-$PGF_{2\alpha}$-treated and 7/8 $PGF_{2\alpha}$-$PGF_{2\alpha}$-treated ewes lambed. Mean gestation length was 147 ± 1 day and was similar among ewes of the two treatment groups as was number of lambs born (1.8 ± 0.1). Retrospective comparison of variables in pregnant and non-pregnant ewes revealed differences ($P < 0.01$) in incidence of estrus and cervical penetration. The 18 pregnant ewes all had expressed estrus and had complete cervical penetration. Nine non-pregnant ewes likewise had expressed estrus and had complete cervical penetration. Intervals from estrus to T-AI and cervical penetration times were similar in pregnant and non-pregnant ewes.

Discussion

Experiment 1. The low pregnancy rate (5%) was unexpected and too low to answer the objective of whether inclusion of teaser rams into the estrous synchronization protocol during the breeding season would improve pregnancy rate following T-AI. Pregnancy rate was 40% in a previous study conducted out-of-season using 500 mg progesterone-containing sponges and T-AI with frozen-thawed semen (Husein et al., 1996). The low pregnancy rate in the present experiment may have been due to poor quality semen. This seems unlikely because few pregnancies (6%) also occurred in a concurrent trial conducted in conjunction with the University of Wisconsin in which 360 ewes were treated with similar sponges and T-AI with frozen-thawed semen from a different ram (D.L. Thomas and R.G. Gottfredson, personal communication). Another possibility is that exogenous progesterone concentrations emanating from the 500 mg progesterone-containing sponges were insufficient during the breeding season. In a follow-up study, plasma progesterone concentrations were determined in ewes following administration of $PGF_{2\alpha}$ and insertion of sponges from the same batch as those used in the present experiment. Plasma samples were collected daily during a 14-day treatment period and progesterone concentrations averaged < 1 ng/mL (Romano et al., 1996). Low progesterone concentrations alter patterns of follicular growth and lead to development of persistent follicles of reduced fertility (Johnson et al., 1996; Thatcher et al., 1996). Such follicles are estrogenic and the early onset of estrus in TR ewes is consistent with increased estradiol concentrations.

Introduction of rams to seasonally anestrous ewes that have been separated from rams for 2 weeks or more induces ovulation (Martin et al., 1986). The "ram effect" elicits an increase in frequency of LH pulses and this effect also has been observed in ewes upon exposure to rams during the breeding season (Martin et al., 1986). Greater progesterone concentrations in TR ewes from days 11 to 14 following sponge removal may have been due to enhanced LH stimulation during the preovulatory period, leading to further development of preovulatory follicles. In cattle LH

Table 1. Reproductive responses of ewes following estrous synchronization using two injections of $PGF_{2\alpha}$ or GnRH and $PGF_{2\alpha}$.

	Treatment	
Item	$PGF_{2\alpha}$-$PGF_{2\alpha}$	GnRH-$PGF_{2\alpha}$
Ewes, number	17	18
Ewes showing estrus, number[a]	12[c]	17[d]
Interval to estrus, hours[b]	38 ± 3[e]	27 ± 3[f]
Pregnant ewes, number	8	10
Lambs born per ewe lambing	1.9 ± 0.1	1.8 ± 0.1

[a] Occurring within 72 hours following the last $PGF_{2\alpha}$ injection.
[b] Checked at 6-hour intervals from the last $PGF_{2\alpha}$ injection.
[c,d] Numbers within row with different superscripts differ ($P = 0.06$).
[e,f] Means within row with different superscripts differ ($P < 0.05$).

pulsing prior to the preovulatory LH surge has a marked effect on subsequent CL size and progesterone secretion (Quintal-Franco et al., 1996). Exposure to rams also may have decreased incidence of premature ovulation and/or luteinization of follicles, manifested by the early (days 2 to 5) rise in progesterone concentrations in NTR ewes. Subsequent spontaneous ovulation in NTR ewes may have elevated progesterone levels on day 20. Although inconclusive, progesterone profiles suggest that introduction of teaser rams coincident with sponge removal may be beneficial to fertility.

Experiment 2. The two estrous synchronization methods tested, two $PGF_{2\alpha}$ injections spaced 11 days apart and GnRH followed 5 days later by $PGF_{2\alpha}$, resulted in similar pregnancy rates following T-AI (47 and 56%, respectively). Beck et al. (1996) previously reported that $PGF_{2\alpha}$-$PGF_{2\alpha}$ and GnRH-$PGF_{2\alpha}$ synchronization procedures produced similar results. The present study and that of Beck and coinvestigators differed in that they used more potent analogs of $PGF_{2\alpha}$ and GnRH rather than natural compounds and they used intact rams for natural mating instead of T-AI. In the present study there was a tendency for a greater incidence of estrus following treatment with GnRH-$PGF_{2\alpha}$ than $PGF_{2\alpha}$-$PGF_{2\alpha}$. This may be attributable to more uniformity in follicular development due to the synchronizing effect of GnRH (Wolfenson et al., 1994). Exogenous GnRH induces a LH surge that evokes ovulation or atresia of existing follicles and thereby initiates a new wave of follicular growth. Intervals to onset of estrus were shorter in GnRH-$PGF_{2\alpha}$-treated than $PGF_{2\alpha}$-$PGF_{2\alpha}$-treated ewes. Three GnRH-$PGF_{2\alpha}$-treated ewes were detected in estrus within 6 hours following administration of $PGF_{2\alpha}$, which contributed largely to the significant difference in intervals to estrus. These ewes may have received GnRH during the late luteal phase of the estrous cycle and been in estrus at the time of $PGF_{2\alpha}$ injection.

Lambing rate achieved in Experiment 2 was similar to that of Buckrell et al. (1994) who used T-AI with frozen-thawed semen in progestogen (MAP)-eCG-treated ewes during the breeding season, and to Halbert et al. (1990) who used T-AI with fresh semen in progestogen (FGA)-eCG-treated ewes during the breeding season. Apparently, GnRH-$PGF_{2\alpha}$, $PGF_{2\alpha}$-$PGF_{2\alpha}$ or aforementioned progestogen-based estrous synchronization protocols possess no clear advantage one over the other for use with T-AI. Data were retrospectively examined to compare responses in ewes that did and did not become pregnant following T-AI. Expression of estrus and full cervical penetration were found to be essential for pregnancy as in previous studies (Husein et al., 1996, 1998). Pregnancy rate was 67% in the subset of ewes that exhibited estrus and were fully penetrated. No other parameters were found to differ, such as intervals from the last $PGF_{2\alpha}$ injection to T-AI, or from onset of estrus to T-AI.

Conclusions

Synchronization of estrus during the breeding season using 500 mg progesterone-containing sponges in conjunction with T-AI with frozen-thawed semen results in low pregnancy rate. Low plasma progesterone concentrations emanating from the sponges may be detrimental to ovarian follicular development during the breeding season. Introduction of teaser rams at the time of sponge removal during the breeding season affects subsequent progesterone profiles. Two estrous synchronization methods that used sequential administration of GnRH and $PGF_{2\alpha}$, or two injections of $PGF_{2\alpha}$, proved equally effective for use with T-AI during the breeding season. Although incidence of estrus tended to be greater and intervals to estrus were shorter in GnRH-$PGF_{2\alpha}$-treated than $PGF_{2\alpha}$-$PGF_{2\alpha}$-treated ewes, pregnancy and lambing rates were similar.

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EAZI-Breed CIDR G Devices versus Prostaglandin $F_{2\alpha}$ for Synchronization of Estrus in Mature Range Ewes

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Summary

Mating was synchronized during the fall breeding season of 168 mature range ewes (1/4 Finn × 3/4 Targhee) using either the EAZI-breed CIDR G device or intramuscular injections of Lutalyse (registered trademark of The Upjohn Company, Kalamazoo, MI; prostaglandin $F_{2\alpha}$ [$PGF_{2\alpha}$]). The CIDR devices contained 0.3 g progesterone and were placed intravaginally for 12 days in 85 ewes. Prostaglandin $F_{2\alpha}$, was administered to 83 ewes in 2 (10 mg) injections, 1 week apart. Breeding was conducted for 5 days beginning 24 hours after the synchronization period ended. Pregnancy rate was determined by ultrasonography on day 60 after breeding. Pregnancy rate was greater (81% ± 3.1%; $P < 0.05$) in ewes that received CIDR devices than in ewes that received $PGF_{2\alpha}$ injections (59% ± 3.3%). In this study CIDR devices outperformed $PGF_{2\alpha}$ as a method for synchronizing mating in mature range ewes during a 5 day breeding period.

Key words: sheep, CIDR, estrus, synchronization.

Introduction

Methods which increase efficiency of production are needed by producers. Many producers have full-time employment away from the farm, which can pose problems during lambing season. Efficient and cost-effective estrous synchronizing techniques would allow these producers to more closely schedule breeding and lambing to occur during periods that are more convenient for them. In addition, synchronization of estrus is necessary for efficient utilization of newly-developed artificial insemination (AI) techniques to reduce insemination time and increase conception rates.

Several methods of estrous synchronization have been developed during the past 30 years. Methods included different means of administration of progesterone, use of other compounds such as prostaglandin $F_{2\alpha}$ and the use of synthetic progesterone agents (progestogens) administered through intravaginal pessaries or subcutaneous implants. In sheep, a controlled internal drug release dispenser (CIDR-G; a solid silicone elastomer progesterone releasing pessary currently marketed in New Zealand and Australia) was developed as an alternative to the progestogen sponge (Welch, 1984; Welch et al., 1984). Numerous studies have compared the efficacy of the CIDR device to other methods of administering progesterone and have found CIDR to be quite successful in the synchronization of estrus in the ewe (Carlson et al., 1989; Wheaton et al., 1990; Wheaton et al., 1992b; Wheaton and Windels, 1994). Lutalyse (prostaglandin $F_{2\alpha}$ [$PGF_{2\alpha}$]) has also been utilized to synchronize estrus (Inskeep et al., 1983; Dinsmore, 1985; Smith et al., 1986; Deaver et. al., 1986). Timing of injection of $PGF_{2\alpha}$ relative to day of the estrous cycle is critical plus it requires two injections, presenting more management problems than with a pessary that can be inserted and removed after a specific time interval.

The objective of this study was to compare the effectiveness of a progesterone releasing intravaginal device (EAZI-breed CIDR G; InterAg, Hamilton, New Zealand) to prostaglandin $F_{2\alpha}$ (Lutalyse; Upjohn, Kalamazoo, MI) on conception rates of ewes synchronized by either method.

Material and Methods

EAZI-breed CIDR G (InterAg, Hamilton, New Zealand) devices were

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implanted in 87 of 168 ewes. The CIDR are a progesterone-releasing intravaginal device containing 9% (0.3 g) progesterone. They were placed in the vagina for 12 days and then removed. The remaining 81 ewes received two injections of Lutalyse (Upjohn, Kalamazoo, MI). Lutalyse ($PGF_{2\alpha}$) was administered intramuscularly in 2 injections (10 mg each), 1 week apart.

All CIDR were implanted 5 days prior to the first injection of Lutalyse so the day of CIDR removal (12 days after implanting) corresponded to the day of the second Lutalyse injection (7 days after the first injection). When the first injection of Lutalyse was administered, ewes that had received CIDR devices were checked to see that the CIDR was still in place. Two ewes lost their CIDR within that 5-day interval; they were moved to the Lutalyse group and administered two shots of Lutalyse. This resulted in 83 ewes treated with Lutalyse and 85 ewes receiving CIDR. Two ewes from the CIDR group were lost to predation on pasture between breeding and day 60 after breeding. Therefore, there were 83 CIDR and 83 Lutalyse treated ewes present when ewes were ultrasounded. After removal of CIDR or second Lutalyse injection ewes were sorted into groups for breeding.

Three pens were utilized during the breeding period. Ewes were sorted and placed in pens that contained approximately the same number of Lutalyse and CIDR treated ewes. Intact rams (1 ram per 15 ewes) were placed with ewes 24 hours after the second Lutalyse injection or CIDR removal (day 0) and continued for 5 days. Every 12 hours rams were rotated to the next pen to limit potential differences among rams. On day 60 post-breeding, ultrasonography was performed on all ewes for detection of pregnancy. Care was taken to determine the number of fetuses present (i.e., single, twin, triplet). Ultrasound data (pregnancy rates, number of fetuses) was analyzed using the catmod procedure of SAS (1985).

Results and Discussion

Pregnancy rates were determined by ultrasonography 60 days after breeding and served as the indicator of the effectiveness of synchronization of conception. Pregnancy rate (Table 1) was greater ($P < 0.01$) in ewes synchronized with CIDR devices than ewes synchronized using Lutalyse. Synchronization rates observed in this study compare with other studies (Henderson et. al., 1984; Acritipoulou-Fourcry et. al., 1982; Hackett et. al., 1981) indicating that CIDR devices are more effective than prostaglandin treatment. Reasons for the lower pregnancy rate in Lutalyse-treated ewes are not clear, but could be due to several factors. These ewes were bred at the end of December, to lamb near the end of May and the beginning of June. It is possible that Lutalyse was not effective in some ewes because they were entering seasonal anestrus. Also, the brief period of exposure to rams (5 days) or the timing of the $PGF_{2\alpha}$ injections may not have been optimal. There is no recommended dosage or timing of injections of Lutalyse for ewes; however, earlier studies have suggested that 15 to 20 mg injections given between 4 and 12 days apart gave optimal results (Boland et al., 1978a,b; Hackett and Robertson, 1980; Hackett et al., 1981; Henderson et al.,1984).

Comparing all treated ewes, the number of fetuses per ewe was greater (1.2 ± 0.04; $P < 0.05$; Table 2) in ewes that received CIDR devices compared with ewes that received $PGF_{2\alpha}$ injections (0.89 ± 0.03). However, when comparing number of fetuses of ewes that conceived, there was no difference between groups. Thus ovulation rate in ewes responding to treatment did not appear to differ among groups.

When considering a synchronizing agent, not only is the cost of the agent important, but also the amount of labor and time involved in the use of the agent are important factors to consider. The cost per ewe for the CIDR device was $3.75. The cost per ewe for Lutalyse (two 10 mg injections) was $2.00. Both agents were easily administered, although placement of CIDR in the vagina did

Table 1. Effects of synchronization method (CIDR or Lutalyse) on pregnancy rate of ewes 60 days after breeding.

Synchronization method	Pregnant	Open	Pregnancy rate, %	SE, %
CIDR	67[a]	16[a]	81	3.1
Lutalyse	49[b]	34[b]	59	3.3

[a,b] Column values with different superscripts differ (P = 0.005).

Table 2. Number of fetuses present in CIDR and Lutalyse ewes 60 days after breeding.[a]

	Number of ewes carrying			Number of fetuses		
Synchronization method	0 fetuses	1 fetus	2 fetuses	Total	Average per ewe	SE
CIDR	16	31	36	103	1.24[b]	0.04
Lutalyse	34	24	25	74	0.89[c]	0.03

[a] Determined by ultrasonography.
[b,c] Column values with different superscripts differ (P = 0.005).

require more time than injecting Lutalyse. However, after implanting only 2 to 3 ewes, the procedure took no more time or effort than the Lutalyse procedure. When ease of application was combined with effectiveness of synchronizing estrus, CIDR were found to be more efficient and cost-effective than the Lutalyse regime utilized in this study.

Currently, there are no commercial sources of the CIDR device in the United States; however, they may be ordered through INTERAG (Te Rapa Road, Hamilton, New Zealand).

Conclusions

Synchronization of estrus will decrease lambing interval as well as produce a uniform set of lambs for market. Producers wanting to synchronize flocks for controlled lambing need an efficient and cost-effective method to accomplish this. EAZI-breed CIDR G devices offer such a method.

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The Influence of Lamb Chronological Age, Slaughter Weight and Gender on Cooking Properties and Palatability[1]

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Summary

Cooking properties and palatability attributes were determined on loin roasts from 1,660 lambs varying in chronological age, slaughter weight (SW) and gender so as to constitute a representative sample of the Canadian market lamb population. Few meaningful differences attributable to gender were detected in cooking properties. However, roasts from ram lambs, in general, were the least tender while roasts from ewe lambs were the most tender. Roasts from ewe lambs also generally had the least amount of perceptible connective tissue; and roasts from ram lambs had the most. Total cooking losses were generally not related to chronological age but increased with SW in roasts from young rams (≤ 6 months) and increased in roasts from ewes and wethers 6 to 9 months of age and wethers 12 to 15 months of age. Cooking times generally decreased with SW and chronological age in roasts from lightweight ram (≤ 49.5 kg) and wether (≤ 40.4 kg) lambs. Degree of doneness decreased with SW in roasts from lambs 9 to 12 months of age and with advancing age in roasts from heavyweight rams and wethers (≥ 50 kg) but increased with advancing age in roasts from lightweight wethers (≤ 40.4 kg). Shear force values generally decreased and initial tenderness generally increased with SW, except in roasts from older rams (≥ 12 months) where the opposite effect was observed, and with advancing age in roasts from heavyweight lambs (≥ 68.2 and ≥ 50 kg, respectively). Overall tenderness generally increased with SW and decreased with advancing age. Although amount of perceptible connective tissue was generally not related to chronological age it generally decreased with SW, except in roasts from older ram lambs (≥ 12 months) where it increased. Juiciness generally increased with advancing age and decreased with SW in roasts from older ram lambs (≥ 6 months). Flavor intensity generally increased with SW in roasts from ram and wether lambs, except in roasts from older ram lambs (≥ 12 months) where it decreased. It also generally increased with advancing age, except in roasts from lightweight wether lambs (≤ 40.4 kg) where it decreased. Therefore, although gender differences in tenderness and the amount of perceptible connective tissue appear clear, specific interactions influence how SW and chronological age affect cooking properties and palatability traits.

Key words: lamb, chronological age, slaughter weight, gender, cooking properties, palatability attributes.

Introduction

Cooking properties and palatability attributes are major determinants of the acceptability of meat products to consumers and such factors have been demonstrated to be influenced by factors inherent to the animals from which the products are derived, such as gender, chronological age and SW. (Jeremiah, 1978).

Production of entire males has been reported to result in faster, more efficient production of leaner meat (Anonymous, 1984) since rams gain faster than ewes and wethers, particularly in the earlier maturing breeds (Dransfield et al., 1990). Moreover, Kirton et al. (1982) observed no differences in the palatability or consumer acceptance of leg roasts attributable to gender and Butler-Hogg et al. (1984) reported the meat from rams and ewes to be equivalent in palatability. In addition, no undesirable odors were detected from meat from entire male lambs (Alvi, 1980; Butler-Hogg et al., 1984; Dransfield et al., 1990). However, Dransfield et

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al. (1990) reported leg roasts from rams were more unacceptable to consumers than their counterparts from ewes and wethers. Jacobson et al. (1962) failed to observe differences in tenderness attributable to gender, but other reports have indicated the meat from ewes and wethers (Summers et al., 1978; Butler-Hogg et al., 1985; Dransfield et al., 1990), ewes and rams (Alvi, 1980) and rams and wethers (Fox et al., 1962; Garrigus et al., 1962; Gates et al., 1964; Pattie et al., 1964; Batcher et al., 1969; Alvi, 1980) differed in tenderness. Dransfield et al. (1990) reported meat from rams had a higher intramuscular collagen content and Butler-Hogg et al. (1985) reported chops from wethers were more juicy than chops from ewes. Alvi (1980) observed no undesirable flavors or aromas attributable to gender and other reports have indicated genders were similar in flavor and flavor intensity (Wilson et al., 1970; Jacobs et al., 1972; Wenham et al., 1973; Kemp et al., 1976; Crouse et al., 1978). However, Butler-Hogg et al. (1985) indicated chops from wethers were more flavorful than chops from ewes and other reports have indicated that meat from rams had a more intense (Cramer et al., 1970; Alvi, 1980; Crouse et al., 1981) and less desirable (Kemp et al., 1972; Misock et al., 1976; Pattie et al., 1964) flavor. A portion of the inconsistency in these findings may arise as a result of age/gender/weight interactions. Crouse et al. (1983) concluded, after a review of the literature, that gender and SW interactions exerted important influences on lamb flavor. Although Field (1971) reported flavor differences between rams and wethers to be small and trends not to be apparent in lambs weighing less than 50 kg live, and Charlet (1969) and Batcher et al. (1969) observed little difference in the flavor of rams and wethers 8 to 12 and 7 to 16 months of age, respectively, other reports have indicated rams up to 72 kg liveweight were more intense in flavor (Crouse et al., 1981). Jacobson et al. (1962) concluded variation among individual animals was greater than variation attributable to differences in gender.

Lowe (1948) reported the animal's age at the time of slaughter constituted one of the major determinants of meat tenderness and Barwick (1980) concluded the consumers' best guide to eating quality was animal age. Ramsey (1984) also reported maturity had a substantial influence on palatability, particularly tenderness. Smith et al. (1969) reported chronological age as a meaningful indicator of lamb tenderness and palatability but indicated chronological age as more highly related to the palatability attributes of leg roasts and loin chops than maturity score. Bruwer et al. (1987) reported tenderness, juiciness, flavor and collagen solubility decreased with advancing animal age and observed a marked decrease in collagen solubility after 4 months of age. However, Butler-Hogg et al. (1985) observed similar juiciness ratings for spring lambs and hoggets Pinkas et al. (1978) also observed decreases in tenderness with advancing age and Jeremiah et al. (1971) reported chronological age was related to both tenderness and cooking losses. Many other reports have demonstrated significant inverse relationships between the animal's age or physiological maturity and meat tenderness, but some reports have indicated these relationships were inconsistent or nonexistent (Jeremiah, 1978). Devine et al. (1993) observed 7-month-old lambs to be slightly more tender than 14-month-old lambs when the muscle pH was equivalent, but indicated the meat from 14-month-old lambs was the most tender when it had high muscle pH. Butler-Hogg et al. (1985) reported that meat from hoggets was more tender and flavorful than the meat from spring lambs. However, Field et al. (1978) reported the flavor of older 68-kg ram lambs was less desirable than the flavor of younger 41-kg ram lambs. Other workers have observed flavor intensity to increase (Weller et al., 1962; Paul et al., 1964) and flavor desirability to decrease (Misock et al., 1976) with advancing age in lambs at very heavy weights (80 kg). However, the reported correlations between age and flavor desirability were very low and there was no linear trend (Misock et al., 1976). Crouse et al. (1982) indicated maturity was not related to lamb flavor and Paul et al. (1964) failed to detect age differences in flavor between wethers 5.5 and 11.5 months of age. Jacobson et al. (1962) concluded the variation among animals was greater than the variation due to age. Such inconsistency in findings may be partially due to the effects of cooking. Schmidt et al. (1968) reported internal temperatures above 60 °C masked tenderness differences attributable to animal age and Walter et al. (1965) reported chronological age and physiological maturity were manifested through cooking possibly as a response of stromal (connective tissue) proteins to heat. Jeremiah et al. (1971) concluded the detrimental effects of advancing chronological age or physiological maturity on tenderness may be manifested through a drying effect during cooking.

Although Channon (1990) indicated production of larger lamb carcasses would increase profitability for the industry, 45% of Australian retailers declined to purchase larger lamb carcasses due to excessively large primal and retail cuts and their perceived lower meat quality and palatability. Kemp et al. (1976) observed SW to influence total cooking losses, shear force values and flavor. However, Sanudo et al. (1996) reported that juiciness increased with carcass weight while all other palatability attributes were not affected, and Jacobs (1972) reported that heavy wethers were more acceptable in palatability than light wethers.

Crouse et al. (1983) observed mutton flavor became more intense as SW increased from 50 to 69 kg. However, Weller et al. (1962) observed flavor intensity to decrease as SW increased and Kemp et al. (1976) reported the flavor of both ewes and wethers became more desirable as SW increased from 36 to 54 kg. Other reports have indicated increases in SW did not influence either shear force values (Wise, 1978) or flavor (Crouse et al., 1982). Crouse et al. (1981) reported increasing SW of rams and ewes from 62 to 76 kg had no effect on flavor. Mendenhall and Erchanbrack (1979) reported the flavor of rams, ewes and wethers slaughtered between 41 and 71 kg was highly acceptable to consumers. A portion of the apparent inconsistency in these reports may result from the fact that consumers are divided on their response to intense lamb flavor (Field et al., 1982).

The present study was undertaken to determine the influences of chronological age, SW and gender on the cooking properties and palatability attributes of loin roasts from animals representative of the Canadian market lamb population.

Materials and Methods

A total of 1,660 lambs were selected on the basis of age, SW, gender and fatness to fill specific subclasses in an experimental design grid (Jeremiah et al., 1997). The lambs evaluated were a representative sample of the entire range of lambs currently being marketed in Canada, rather than a set of animals of controlled breeding and dietary management, slaughtered at different weights and/or ages. The lambs in the present study were purchased from commercial sheep producers with breeding records and certified birthdates for the lambs purchased, so that both the breeding and chronological ages could be ascertained. The lambs were predominantly crossbreds, involving some combination of the following breeds: Cheviot, Columbia, Dorset, Finnish Landrace, Hampshire, Leicester, Montadale, Rambouillet, Romanoff, Romney, Shropshire, Southdown, Suffolk, Targhee and/or Texel. Breeds and breed-crosses were allocated as evenly as possible among age/weight/gender subclasses and care was taken to prevent a given breed or breed-cross from constituting a majority in any given age/weight/gender subclass.

Fatness and gender were ascertained the day prior to slaughter. Fatness was ascertained both subjectively by a trained and experienced evaluator and ultrasonically, and the same fatness criteria were applied to all age/SW/gender subclasses. Breed composition necessarily varied among age/SW subclasses, but was relatively constant within subclasses. Since the lambs were purchased from different producers, it is possible they were fed differently and it is also possible this may have influenced compositional properties. The actual frequency distribution of lambs evaluated has been presented (Jeremiah et al., 1997) by age, weight, gender and fatness subclass.

Loin roasts between the 12th thoracic and the most posterior lumbar vertebra were removed from the right side of each lamb carcass. Each wholesale loin was weighed, vacuum packaged and frozen at -30 °C in still air. They were then held at this temperature until evaluated (90 to 180 days). Upon removal from the freezer, all loins were thawed at 4 °C for 48 hours and then reweighed to determine thaw-drip losses. A saber thermocouple was then inserted into the center of each loin and they were roasted in an electric convection oven preheated to 177 °C to an internal temperature of 75 °C. Upon removal from the oven each loin was reweighed to determine total cooking losses, a cross-sectional surface of each loin was subjectively evaluated for degree of doneness (1 = rare; 5 = well done) and cooking times were recorded. Six 1.9-cm^3 cubes were then removed from each loin, taking care to avoid large pieces of fat and connective tissue, and randomly assigned to an experienced six-member taste panel screened and trained according to AMSA guidelines (AMSA, 1978). Sub-samples were held in covered glass containers in a 70 °C water bath until evaluated (10 to 15 minutes).

Panel sessions were conducted in well ventilated temperature-controlled partitioned booths under 1,076 lux of incandescent and fluorescent white light. Room temperature distilled water and unsalted soda crackers were provided to remove flavor residues between sample evaluations (Larmond, 1977). Panelists evaluated sub-samples using eight-point descriptive scales for initial and overall tenderness (8 = extremely tender; 1 = extremely tough), amount of perceptible connective tissue (8 = no perceptible connective tissue; 1 = abundant perceptible connective tissue), juiciness (8 = extremely juicy; 1 = extremely dry) and flavor intensity (8 = extremely intense lamb flavor; 1 = extremely bland lamb flavor). The presence of any off-flavor was also noted.

Three 13-mm cores were also removed from each loin parrallel to the muscle fibers using a mechanical cork borer after the loins had been refrigerated overnight at 4 °C. Each core was then sheared three times using the Ottawa Texture Measuring System fitted with a Warner-Bratzler blade and mean shear force values were calculated and recorded.

Data were analyzed using the general linear model (GLM) procedures of SAS (SAS, 1985). Sources of variation were age, SW, gender and their 2-way and 3-way interactions. Mean separation of significant main effects was by single degree of freedom linear contrasts. Linear regression was used to detect significant trends with advancing age and increasing SW (Puri and Mullen, 1980).

Results and Discussion

In general, roasts from rams sustained lower drip cooking losses ($P < 0.05$) than those from wethers (Table 1). Roasts from ewes also generally sustained greater drip cooking losses ($P < 0.05$) than those from wethers, except at older ages and heavier weights (Age Group 4, Weight Group 5) where the opposite effects were observed. Cooking drip losses increased progressively with increasing SW in roasts from rams (Age Groups 1, 2 and 3; $r^2 = 0.76$ to 0.90, $P < 0.05$), ewes (Age Groups 1 and 3; $r^2 = 0.90$ and 0.77, respectively, $P < 0.05$) and wethers (Age Groups 1, 2 and 4; $r^2 = 0.83$ to 0.94, $P < 0.05$). Cooking drip losses were not generally related to chronological age. The fact that roasts from ewes sustained the greatest cooking drip losses while those from rams sustained the lowest reflects the differences demonstrated in fatness (Jeremiah et al., 1997). The positive trends in cooking drip losses observed with increasing SW reflect the demonstrated increases in fatness observed with increasing SW (Jeremiah et al., 1997).

Roasts from ewes and wethers generally sustained lower evaporative cooking losses than those from rams (Table 2). Roasts from wethers also sustained greater evaporative cooking losses than those from ewes at young ages and heavier weights (Age Group

Table 1. Least-square means (LSM) and standard errors (SE) for percent cooking drip losses from lamb roasts from various age/weight/gender subclasses.

	Slaughter Weight Group, kg									
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)	
Gender	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Age Group 1 (3 to 6 months):										
Rams	5.81	0.64	6.61^{b}	0.60	7.63^{b}	0.58	10.36	0.61	9.83	2.91
Ewes	6.29	0.63	8.87^{a}	0.64	10.56^{a}	0.56	11.65	0.64	–	–
Wethers	7.40	0.60	8.26^{a,b}	0.61	10.27^{a}	0.64	10.63	0.64	–	–
Age Group 2 (6 to 9 months):										
Rams	5.94	2.07	7.23^{b}	0.53	9.03^{b}	0.50	11.54	0.51	12.00^{b}	0.54
Ewes	13.11	2.91	9.56^{a}	0.50	10.60^{a}	0.51	12.36	0.51	16.06^{a}	0.54
Wethers	–	–	9.09^{a}	0.48	9.61^{a,b}	0.47	11.05	0.51	12.52^{b}	0.54
Age Group 3 (9 to 12 months):										
Rams	3.49	2.07	5.60^{c}	0.53	6.83^{c}	0.50	8.62^{c}	0.50	10.49^{b}	0.54
Ewes	–	–	10.26^{a}	0.52	12.24^{a}	0.50	13.84^{a}	0.52	15.33^{a}	0.54
Wethers	8.85	2.91	8.10^{b}	0.52	8.78^{b}	0.50	10.78^{b}	0.52	11.67^{b}	0.52
Age Group 4 (12 to 15 months):										
Rams	–	–	11.50	2.91	8.40^{b}	0.54	9.33^{b}	0.50	10.40^{b}	0.49
Ewes	15.47	2.91	12.23	2.07	11.30^{a}	0.55	11.48^{a}	0.49	10.53^{b}	0.48
Wethers	–	–	5.19	2.91	10.30^{a}	0.54	11.94^{a}	0.50	13.99^{a}	0.44

^{a,b,c} Means in the same column and age group without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

Table 2. Least-square means (LSM) and standard errors (SE) for percent evaporative cooking losses from lamb roasts from various age/weight/gender subclasses.

	Slaughter Weight Group, kg									
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)	
Gender	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Age Group 1 (3 to 6 months):										
Rams	27.19	0.72	25.56^{a}	0.68	24.11^{a}	0.66	21.55^{a,b}	0.70	22.17	3.31
Ewes	25.67	0.71	22.76^{b}	0.72	23.32^{a}	0.56	22.28^{a}	0.57	20.85	0.61
Wethers	26.75	0.69	24.94^{a}	0.70	20.53^{b}	0.72	20.42^{b}	0.72	–	–
Age Group 2 (6 to 9 months):										
Rams	25.88	2.35	24.71^{a}	0.60	23.04^{a}	0.56	21.13	0.58	21.57^{a}	0.61
Ewes	18.11	3.31	22.44^{b}	0.57	22.94^{a,b}	0.58	19.93	0.58	17.72^{b}	0.61
Wethers	–	–	23.53^{a,b}	0.55	21.51^{b}	0.53	20.26	0.58	20.36^{a}	0.61
Age Group 3 (9 to 12 months):										
Rams	28.43	2.35	23.08^{a}	0.60	23.32^{a}	0.56	22.28^{a}	0.57	20.85^{a}	0.61
Ewes	–	–	18.36^{c}	0.60	12.53^{c}	0.57	17.53^{c}	0.60	17.36^{b}	0.61
Wethers	22.16	3.31	20.33^{b}	0.60	20.39^{b}	0.56	20.41^{b}	0.60	19.58^{a}	0.60
Age Group 4 (12 to 15 months):										
Rams	–	–	19.91	3.31	22.32^{a}	0.61	22.13^{a}	0.57	22.01^{a}	0.56
Ewes	18.03	3.31	19.86	2.35	18.27^{b}	0.62	19.27^{b}	0.56	17.55^{b}	0.54
Wethers	–	–	23.02	3.31	19.51^{b}	0.61	19.93^{b}	0.57	18.29^{b}	0.50

^{a,b,c} Means in the same column and age group without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

1; Weight Groups 3 and 4). Evaporative cooking losses decreased progressively with increasing SW in roasts from rams (Age Groups 1, 2 and 3; $r^2 = 0.83$ to 0.96, $P < 0.05$), ewes (Age Group 1; $r^2 = 0.92$, $P < 0.01$), and wethers (Age Groups 1, 2, 3 and 4; $r^2 = 0.79$ to 0.94, $P < 0.05$), except in roasts from older rams (Age Group 4) where they increased progressively. Evaporative cooking losses also decreased with advancing age in roasts from medium weight rams (Weight Groups 2 and 3; $r^2 = 0.86$ and 0.83, respectively, $P < 0.05$). Differences in evaporative cooking losses attributable to gender also reflect demonstrated differences in fatness (Jeremiah et al., 1997) since evaporative cooking losses are inversely related to fat content. Likewise, the negative trends in evaporative cooking losses detected with increasing SW reflect demonstrated trends in lean content with increases in SW (Jeremiah et al., 1997).

Total cooking losses did not differ due to gender in any of the age/weight subclasses ($P > 0.05$). Total cooking losses increased (data not shown in tabular form) with increasing SW in roasts from ewes (Age Group 2; $r^2 = 0.67$, $P < 0.05$) and wethers (Age Groups 2 and 4; $r^2 = 0.77$ and 0.85, respectively, $P < 0.05$) but decreased with increasing SW in roasts from young rams (Age Group 1; $r^2 = 0.79$, $P < 0.05$). Total cooking losses also decreased progressively with advancing age in roasts from wethers (Weight Group 2; $r^2 = 0.79$, $P < 0.05$). The general lack of trends in total cooking losses observed in the present study with advancing age is contrary to a previous report that chronological age was related to cooking losses (Jeremiah et al., 1971).

Differences in cooking times were not observed among genders in any of the age/weight subclasses ($P > 0.05$; data not shown in tabular form). Cooking times generally decreased progressively with increasing SW in roasts from rams (Age Groups 1, 2, 3 and 4; $r^2 = 0.90$ to 0.98, $P < 0.05$), ewes (Age Groups 1 and 4; $r^2 = 0.94$ and 0.90, respectively, $P < 0.05$) and wethers (Age Groups 1, 2, 3 and 4; $r^2 = 0.79$ to 0.99, $P < 0.05$). The only trend observed in cooking times with advancing age was a negative trend in rams in Weight Group 2 ($r^2 = 0.92$, $P < 0.01$).

Significant differences in degree of doneness due to gender were not detected ($P > 0.05$) in any age/weight subclass (data not shown in tabular form). Degree of doneness decreased progressively with increasing SW in roasts from lambs in Age Group 3 (rams: $r^2 = 0.77$; ewes: $r^2 = 0.77$; wethers: $r^2 = 0.86$, $P < 0.05$) but increased progressively with increasing SW in roasts from ewes in Age Group 2 ($r^2 = 0.83$, $P < 0.05$). Degree of doneness also generally decreased progressively with advancing age in roasts from heavyweight ewes (Weight Groups 4 and 5; $r^2 = 0.86$ and 0.92, respectively, $P < 0.05$) and wethers (Weight Groups 3 and 5; $r^2 = 0.77$ and 0.92, respectively, $P < 0.05$).

Roasts from wethers had higher mean shear force values than those from rams and ewes at younger ages and lighter weights (Table 3). Roasts from ewes also had higher mean shear force values than those from rams at the

Table 3. Least-square means (LSM) and standard errors (SE) for shear force values of roasts from lambs in various age/weight/gender subclasses.

	Slaughter Weight Group, kg									
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)	
Gender	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Age Group 1 (3 to 6 months):										
Rams	3.12[b]	0.15	3.23[b]	0.14	3.00[a]	0.13	2.61	0.14	2.67	0.67
Ewes	3.54[a]	0.14	3.09[b]	0.15	2.55[b]	0.13	2.64	0.15	–	–
Wethers	3.82[a]	0.14	3.57[a]	0.14	2.77[a,b]	0.15	2.90	0.15	–	–
Age Group 2 (6 to 9 months):										
Rams	4.02	0.47	3.21[b]	0.12	3.21	0.11	2.77	0.12	2.90	0.12
Ewes	4.05	0.67	3.17[b]	0.11	3.00	0.12	3.03	0.12	2.63	0.12
Wethers	–	–	3.74[a]	0.11	3.32	0.11	2.83	0.12	2.64	0.12
Age Group 3 (9 to 12 months):										
Rams	3.55	0.47	3.07	0.12	3.32[a]	0.11	3.02[a]	0.11	3.02	0.12
Ewes	–	–	2.80	0.12	2.72[b]	0.11	2.52[b]	0.12	2.75	0.12
Wethers	4.53	0.67	2.97	0.12	2.89[b]	0.11	2.81[a,b]	0.12	2.76	0.12
Age Group 4 (12 to 15 months):										
Rams	–	–	2.55	0.67	3.06	0.12	3.32[a]	0.11	3.07	0.11
Ewes	2.37	0.67	3.07	0.47	2.82	0.12	2.85[b]	0.11	2.88	0.11
Wethers	–	–	3.36	0.67	2.87	0.12	2.93[b]	0.12	2.84	0.10

[a,b] Means in the same column and age group without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

youngest ages and lightest weights. However, roasts from rams generally had higher shear force values than those from wethers and ewes at heavier weights and older ages. Mean shear force values decreased with increasing SW in roasts from rams (Age Groups 2 and 3; $r^2 = 0.74$ to 0.96, $P < 0.05$), ewes (Age Groups 1 and 2; $r^2 = 0.88$ to 0.96, $P < 0.05$) and wethers (Age Groups 2, 3, and 4; $r^2 = 0.88$ to 0.92, $P < 0.05$) but increased progressively with increasing SW in roasts from older rams (Age Group 4; $r^2 = 0.80$; $P < 0.05$). Mean shear force values also generally increased with advancing age in roasts from heavier lambs (rams and ewes: Weight Groups 4 and 5; $r^2 = 0.92$ to 0.96, $P < 0.01$; wethers: Weight Group 5; $r^2 = 0.98$, $P < 0.01$). Although Wise (1978) previously reported ewes to have lower shear values than wethers, this was only the case in the present study when they were in Age Groups 1 and 2 and Weight Group 2. Moreover, the significant trends in shear force values with increasing SW observed in the present study appear contrary to the previous conclusion that increases in SW did not influence shear force values (Wise, 1978).

Roasts from ewes were generally rated higher in initial (first bite) tenderness ($P < 0.05$) than those from rams and wethers (data not shown in tabular form). Roasts from wethers were also rated higher in initial tenderness ($P < 0.05$) than those from rams at mid ages and weights (Age Group 3; Weight Group 3). Such differences are contrary to a previous conclusion that tenderness was unaffected by gender (Jacobson et al., 1962). Initial tenderness increased progressively with increasing SW in roasts from young rams under 12 months of age (Age Groups 1, 2 and 3; $r^2 = 0.69$ to 0.96, $P < 0.05$) but decreased progressively with increasing SW in roasts from older rams (Age Group 4; $r^2 = 0.85$, $P < 0.05$). Such trends clearly indicate initial tenderness increased progressively with SW in rams until 12 months of age and then decreased progressively between 12 and 15 months of age. With ewes and wethers, initial tenderness generally increased with increasing SW (ewes: Age Groups 2 and 4; $r^2 = 0.92$, $P < 0.05$; wethers: Age Groups 2, 3 and 4; $r^2 = 0.81$ to 0.92, $P < 0.05$). Initial tenderness generally decreased progressively with advancing age in heavyweight rams and wethers ($r^2 = 0.81$ to 0.99, $P < 0.05$), indicating advancing age had a detrimental effect on the initial tenderness of heavyweight rams and wethers. Initial tenderness also decreased progressively with advancing age in midweight ewes (Weight Group 3; $r^2 = 0.94$, $P < 0.01$). Such trends lend support to previous reports of significant relationships between tenderness and chronological age (Jeremiah et al., 1971; Ramsey, 1984) and decreases in tenderness with advancing age (Pinkas et al., 1978).

Roasts from ewes generally were rated higher in overall tenderness than those from rams and wethers (Table 4). In addition, roasts from wethers

Table 4. Least-square means (LSM) and standard errors (SE) for overall tenderness scores[a] of roasts from lambs in various age/weight/gender subclasses.

	Slaughter Weight Group, kg									
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)	
Gender	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Age Group 1 (3 to 6 months):										
Rams	4.61	0.27	4.99	0.25	5.33[c]	0.24	5.80	0.26	6.59	1.22
Ewes	4.93	0.26	5.52	0.27	6.51[b]	0.23	6.02	0.27	–	–
Wethers	4.45	0.25	4.84	0.26	6.06[b,c]	0.27	5.71	0.27	–	–
Age Group 2 (6 to 9 months):										
Rams	4.00	0.87	4.30[c]	0.22	4.61[c]	0.21	5.57	0.21	5.24[c]	0.23
Ewes	3.59	1.22	5.18[b]	0.21	5.67[b]	0.21	5.32	0.21	6.31[b]	0.23
Wethers	–	–	4.70[b,c]	0.21	4.98[c]	0.20	5.44	0.21	5.43[c]	0.23
Age Group 3 (9 to 12 months):										
Rams	2.34	0.87	3.95[d]	0.22	3.97[d]	0.21	4.68[c]	0.21	4.96	0.23
Ewes	–	–	5.55[b]	0.22	5.83[b]	0.21	5.89[b]	0.22	5.26	0.23
Wethers	3.42	1.22	4.76[c]	0.22	4.85[c]	0.21	4.98[c]	0.22	5.06	0.22
Age Group 4 (12 to 15 months):										
Rams	–	–	5.25	1.22	4.17[c]	0.23	4.03[c]	0.21	4.43[c]	0.21
Ewes	4.92	1.22	4.67	0.87	4.88[b]	0.23	5.24[b]	0.21	5.25[b]	0.20
Wethers	–	–	3.75	1.22	4.40[b,c]	0.23	4.83[b]	0.21	4.65[c]	0.18

[a] Overall tenderness scores: 8 = extremely tender; 1 = extremely tough.

[b,c,d] Means in the same column and age group without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

also received higher overall tenderness ratings ($P < 0.05$) than those from rams in Age Group 3 and Weight Groups 2 and 3. These differences also disagree with the previous report that differences in tenderness attributable to gender did not exist (Jacobson et al., 1962). Overall tenderness generally increased progressively with increasing SW (rams: Age Groups 1, 2 and 3; $r^2 = 0.72$ to 0.98; ewes: Age Group 2; $r^2 = 0.92$; wethers: Age Groups 2, 3 and 4; $r^2 = 0.83$ to 0.94, $P < 0.05$), also demonstrating the beneficial effects of increasing SW on tenderness. Overall tenderness generally decreased progressively with advancing age (rams and wethers: Weight Groups 3, 4 and 5; $r^2 = 0.84$ to 0.86, $P < 0.05$; ewes: Weight Group 3; $r^2 = 0.85$, $P < 0.05$) demonstrating the detrimental effects of advancing age on tenderness. Such trends support the existence of the significant relationships previously observed between chronological age and tenderness (Jeremiah et al., 1971; Ramsey, 1984) and the decrease in tenderness with advancing age reported by Pinkas et al. (1978).

In general, roasts from ewes had less perceptible connective tissue ($P < 0.05$) than those from rams and young wethers (Age Group 1; Table 5). In addition, roasts from wethers had less perceptible connective tissue than those from rams at mid ages and weights (Age Group 3; Weight Group 3). The amount of perceptible connective tissue generally decreased progressively with increasing SW (rams: Age Groups 1, 2 and 3; $r^2 = 0.77$ to 0.94; ewes: Age Groups 1, 2 and 4; $r^2 = 0.88$ to 0.98; wethers: Age Groups 1, 3, and 4; $r^2 = 0.88$ to 0.98, $P < 0.05$) but increased progressively in roasts from older rams (Age Group 4; $r^2 = 0.77$, $P < 0.05$). Such results indicate that connective tissue generally becomes less perceptible with increasing SW but becomes more perceptible with increasing SW in rams over 12 months of age. Significant trends in the amount of perceptible connective tissue with advancing age were not detected in any of the age/weight/gender subgroups ($P > 0.05$).

Differences in juiciness attributable to gender, when detected, were inconsistent (Table 6). Juiciness decreased progressively with increasing SW in roasts from rams in Age Groups 2 and 4 ($r^2 = 0.88$ to 0.98, $P < 0.05$). Juiciness generally increased progressively with advancing age (rams: Weight Groups 2 and 5; ewes: Weight Group 5; wethers: Weight Group 1; $r^2 = 0.90$ to 0.99, $P < 0.05$).

Differences in flavor intensity due to gender were not observed ($P > 0.05$) in any of the age/weight/gender subclasses (Table 7), which supports several reports that rams and wethers did not differ in flavor intensity (Crouse et al., 1978; Jacobs et al., 1872; Kemp et al., 1876; Wenham et al., 1978; Wilson et al., 1970), but is contrary to other reports that rams had more intense flavor than wethers (Crouse et al., 1978 and 1981) and heavy rams were intense in flavor (Crouse, 1983). Flavor intensity

Table 5. Least-square means (LSM) and standard errors (SE) for perceptible connective tissue scores[a] of roasts from lambs in various age/weigh/gender subclasses.

	Slaughter Weight Group, kg									
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)	
Gender	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Age Group 1 (3 to 6 months):										
Rams	5.46	0.24	6.08[b,c]	0.22	6.44[c]	0.21	7.13[c]	0.23	7.93	1.07
Ewes	5.82	0.23	6.55[b]	0.23	7.51[b]	0.20	7.81[b]	0.23	–	–
Wethers	5.39	0.22	5.80[c]	0.22	6.92[b,c]	0.23	7.06[c]	0.23	–	–
Age Group 2 (6 to 9 months):										
Rams	4.26	0.76	5.94	0.19	6.17	0.18	7.22	0.19	6.85[c]	0.20
Ewes	3.93	1.07	6.39	0.18	6.67	0.19	6.82	0.19	7.62[b]	0.20
Wethers	–	–	5.91	0.18	6.39	0.17	7.23	0.19	7.34[b,c]	0.20
Age Group 3 (9 to 12 months):										
Rams	5.85	0.76	6.62[c]	0.19	6.21[d]	0.18	6.89[c]	0.18	7.19	0.20
Ewes	–	–	7.56[b]	0.19	7.63[b]	0.18	7.67[b]	0.19	7.32	0.20
Wethers	5.93	1.07	7.06[b,c]	0.19	7.04[c]	0.18	7.04[c]	0.19	7.09	0.19
Age Group 4 (12 to 15 months):										
Rams	–	–	7.43	1.07	6.67	0.20	6.57[c]	0.18	6.84[c]	0.18
Ewes	6.10	1.07	6.43	0.76	6.90	0.20	7.15[b]	0.18	7.28[b]	0.17
Wethers	–	–	5.43	1.07	6.75	0.20	6.88[b,c]	0.19	6.87[b,c]	0.16

[a] Perceptible connective tissue scores: 8 = no perceptible connective tissue; 1 = abundant perceptible connective tissue.

[b,c,d] Means in the same column and age group without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

generally increased progressively with SW (rams: Age Groups 1, 2 and 3; wethers: Age Groups 2 and 3; r^2 = 0.76 to 0.99, $P < 0.05$) indicating flavor intensity increased progressively with increasing SW in rams and wethers less than 12 months of age. However, flavor intensity decreased progressively with increasing SW in older rams (Age Group 4; r^2 = 0.81, $P < 0.05$). These trends appear contrary to previous reports that flavor intensity decreased with increases in SW (Weller et al., 1962) and heavy ram lambs had intense flavor (Crouse, 1983). Flavor intensity generally increased progressively with advancing age (rams: Weight Group 5; ewes: Weight Group 2; wethers: Weight Groups 2 and 3; r^2 = 0.83 to 0.96, $P < 0.05$) which is contrary to previous reports that flavor intensity decreased with advancing age (Weller et al., 1962; Paul et al., 1964).

Conclusions

Roasts from ram lambs generally sustained the lowest cooking drip losses and the highest cooking evaporative losses. However, differences attributable to gender were not observed in total cooking losses. Differences attributable to gender were also not observed in either cooking times or degree of doneness. Cooking drip losses generally increased with SW but were not related to chronological age, except in lightweight wether and ewe lambs (≤ 40.4 kg). Cooking evaporative losses generally decreased with SW except in older rams (≥ 12 months). They also decreased with advancing age in lightweight rams (≤ 58.6 kg) and wethers (≤ 40.4 kg). Total cooking losses were generally not related to chronological age. However, they decreased with SW in roasts from young rams (≤ 6 months) and increased with SW in roasts from ewes and wethers 6 to 9 months of age and wethers 12 to 15 months of age. Cooking times for loin roasts generally decreased with SW and chronological age in lightweight ram (≤ 49.5 kg) and wether (≤ 40.4 kg) lambs. Degree of doneness decreased with SW in roasts from lambs 9 to 12 months of age. It also decreased with advancing age in roasts from heavyweight rams and wethers (≥ 50 kg) and increased with advancing age in roasts from lightweight wethers (≤ 40.4 kg). Roasts from rams generally had the highest shear force values when they were at heavier weights (≤ 50 kg) and roasts from wethers generally had the highest shear force values when they were at lighter weights (≤ 50 kg). Shear force values generally decreased with SW, except in roasts from older ram lambs (≥ 12 months) where they increased; and shear force values increased with advancing age in roasts from heavyweight lambs (≥ 68.2 kg). Roasts from ewes were generally rated highest in both initial and overall tenderness. Initial tenderness increased with SW in roasts from young ram lambs (≤ 12 months) and decreased in roasts from older ram lambs (≥ 12 months). Initial tenderness also increased with SW in roasts from older ewe and wether lambs (≥ 6

Table 6. Least-square means (LSM) and standard errors (SE) for the juiciness scores[a] of roasts from lambs in various age/weight/gender subclasses.

	Slaughter Weight Group, kg									
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)	
Gender	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Age Group 1 (3 to 6 months):										
Rams	5.02	0.17	4.90[c]	0.15	4.93[c]	0.15	4.73[c]	0.16	3.58	0.75
Ewes	4.96	0.16	5.38[b]	0.16	5.10[b,c]	0.14	4.95[b,c]	0.16	–	–
Wethers	4.74	0.16	4.85[c]	0.16	5.49[b]	0.16	5.22[b]	0.16	–	–
Age Group 2 (6 to 9 months):										
Rams	5.83	0.53	5.11	0.13	5.30[b]	0.13	4.66	0.13	4.53	0.14
Ewes	4.58	0.75	4.94	0.13	4.35[c]	0.13	4.78	0.13	4.81	0.14
Wethers	–	–	4.96	0.13	5.02[b]	0.12	4.89	0.13	4.72	0.14
Age Group 3 (9 to 12 months):										
Rams	4.75	0.53	5.31	0.14	5.40	0.13	5.19	0.13	4.81	0.14
Ewes	–	–	5.26	0.13	5.24	0.13	5.13	0.13	5.03	0.14
Wethers	6.42	0.75	5.42	0.13	5.37	0.13	5.30	0.13	4.87	0.13
Age Group 4 (12 to 15 months):										
Rams	–	–	5.75	0.75	5.16	0.14	5.15	0.13	4.93	0.13
Ewes	5.25	0.75	5.00	0.53	5.38	0.14	5.11	0.13	5.02	0.12
Wethers	–	–	4.08	0.75	5.24	0.14	4.93	0.13	4.85	0.11

[a] Juiciness scores: 8 = extremely juicy; 1 = extremely dry.

[b,c] Means in the same column and age group without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

months) and generally decreased with advancing age in heavyweight lambs (≥ 50 kg). Overall tenderness generally increased with SW and decreased with advancing age. Roasts from ewe lambs also generally had the least amount of perceptible connective tissue. Amount of perceptible connective tissue generally decreased with SW except in roasts from older ram lambs (≥ 12 months) where it increased. However, amount of perceptible connective tissue was generally not related to chronological age. Consistent differences in juiciness attributable to gender were not observed. Juiciness generally increased with advancing age and decreased with SW in roasts from older ram lambs (≥ 6 months). Differences attributable to gender were also not observed in flavor intensity ratings. Flavor intensity generally increased with SW in roasts from ram and wether lambs except in roasts from older ram lambs (≥ 12 months). Flavor intensity also generally increased with advancing age except in roasts from lightweight wether lambs (≥ 40.4 kg) where it decreased.

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Table 7. Least-square means (LSM) and standard errors (SE) for flavor intensity scores[a] of roasts from lambs in various age/weight/gender subclasses.

	Slaughter Weight Group, kg									
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)	
Gender	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Age Group 1 (3 to 6 months):										
Rams	4.50	0.11	4.81	0.10	4.94	0.10	5.06	0.11	5.12	0.50
Ewes	4.64	0.11	4.46	0.11	4.80	0.10	4.92	0.11	–	–
Wethers	4.56	0.10	4.49	0.11	4.77	0.11	4.89	0.11	–	–
Age Group 2 (6 to 9 months):										
Rams	4.21	0.36	4.73	0.09	5.00	0.09	4.93	0.09	4.96	0.09
Ewes	4.62	0.50	4.75	0.09	4.44	0.09	4.76	0.09	4.84	0.09
Wethers	–	–	4.48	0.09	4.81	0.08	4.89	0.09	4.95	0.09
Age Group 3 (9 to 12 months):										
Rams	4.46	0.36	4.77	0.09	4.80	0.09	4.95	0.09	4.84	0.09
Ewes	–	–	4.91	0.09	4.94	0.09	5.01	0.09	4.97	0.09
Wethers	4.29	0.50	4.98	0.09	4.94	0.09	4.98	0.09	4.89	0.09
Age Group 4 (12 to 15 months):										
Rams	–	–	5.29	0.50	4.85	0.09	5.01	0.09	4.81	0.09
Ewes	5.29	0.50	5.79	0.36	4.90	0.09	5.00	0.09	5.20	0.08
Wethers	–	–	5.29	0.50	4.98	0.09	4.92	0.09	5.06	0.08

[a] Flavor intensity scores: 8 = extremely intense lamb flavor; 1 = extremely bland lamb flavor.

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Research Briefs

Responses to Various Selection Protocols for Lamb Production in Rambouillet, Targhee, Columbia and Polypay Sheep

S.K. Ercanbrack and A.D. Knight
USDA, Dubois ID 83423

Cited from: J. Anim. Sci. 76:1311-1325.

Ewe productivity has been identified as the major factor contributing to improved efficiency of sheep production. In recent years, the relative income from lamb and wool suggests that increased lamb production should receive greater emphasis. In the past, little selection has been practiced for ewe productivity. Lamb production may be a function of ewe fertility (% lambing), fecundity (litter size at birth), lamb survival and lamb growth rate. Litter weight weaned is a composite trait comprised of all the above factors. The present study involved 25,026 ewe records covering a 13-year period (12 years of selection) within the Rambouillet, Targhee, Columbia and Polypay breeds. The experimental animals consisted of 11 lines (9 selected, 2 controls). The selection protocols evaluated included litter weight weaned, independent culling levels for litter weight, early puberty and body weight, as well as the two control lines. The results indicate significant gains (increases) in litter weight weaned, net reproductive rate, prolificacy, body weight, weaning weight and milk production score. In most lines there were significant, but modest, declines in fleece weight. Genetic improvement in litter weight weaned was attributed approximately 37% to prolificacy, 27% to weaning percent, 17% to weaning weight, 12% to fertility and 7% to ewe viability. On average selection based on independent culling levels, yearling body weight and early puberty was only 85, 67 and 59%, respectively, as efficient as that based on litter weight weaned. The authors estimate that the net (market) value of genetic gains from selection for litter weight weaned exceeded \$10.00 per ewe year (\$11.40). Trends within the lines provide interesting observations in respect to selection practices.

In the mind of this reviewer, it should be realized that no increase in productivity comes totally free as additional feed intake will be required to support the increased production. This is especially true in this study where increased body weights and reduced fleece weights were a correlated response to selection.

Prepared by Maurice Shelton.

Colour Variation and Reproduction in West African Dwarf (WAD) Goats

M.O. Ebozoje and C.O.N. Ikeobi
University of Agriculture, P.M.B. 2240, Abeokuta, Nigeria

Cited from: Small Ruminant Research 27:125.

In this study, 720 West African Dwarf (WAD) does were classified in respect to colour (amount of pigment) into four groups ranging from black to white or spotted. Reproductive data were recorded including fertility (%), prolificacy (number of offspring per litter, %), fecundity (number of offspring per year, %), age at kidding (months), kidding interval (months), gestation length (days), along with birth and weaning weight and mortality. Although not significant in all cases, performance (reproduction, growth, survival) tended to favor the darker coloured does in all variables measured. The authors do not provide a definitive explanation for the observed differences, but superior adaptation to the African environment or a suppressive action for the gene for white colour is suggested.

In this reviewer's opinion, the WAD goat and/or the African environment differs sufficiently that this work needs repetition or validation with other genotypes or other environments. However, if these findings are born out by other studies it carries important implications for goat producers.

Prepared by Maurice Shelton.

Sheep & Goat Research Journal
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Objective

The aim of the Sheep & Goat Research Journal is to provide a publication of sheep and goat research findings which can be used by scientists, educators, Extension agents and sheep and goat producers alike. The specific goal of the Journal is to gather and distribute current research information on all phases of sheep and goat production and to encourage producer use of research which has practical application. The Journal is published three times each year.

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Evaluation of the Sirolan-Laserscan for Measuring Wool Fiber Diameter and Standard Deviation

R.H. Stobart[1,2], R.S. Townsend[1] and W.C. Russell[1]

Summary

The Sirolan-Laserscan (LS) measures fiber diameter using a Fresnel diffraction-based shadowing technique. Fiber snippets carried in a dilute slurry suspension pass through a laser beam and variations in the beam intensity convert directly to individual fiber measurements. A supplementary fiber optic discrimination system rejects measurement events such as crossed fibers, dirt or fragments and fibers only partially intersecting the beam. This system was developed to provide a rapid accurate measurement of average fiber diameter (AFD) and distribution of diameter measured as standard deviation (SD) of animal fibers. An interlaboratory test was conducted to evaluate results produced by the LS compared to the standard projection microscope (PM) method of the American Society for Testing and Materials (ASTM). The LS was calibrated with 8 Interwool-labs (International Association of Wool Textile Laboratories) IH tops in accordance with an International Wool Textile Organization's (IWTO) test method under examination. The LS was then used to measure 9 wool tops that had been extensively characterized by 10 or more U.S. fiber labs using the standard ASTM PM method. No differences ($P > 0.05$) were observed between the LS and PM for 7 of the 9 tops. The other 2 tops were different ($P < 0.01$). The differences in AFD between the LS and PM ranged from 0.18 to -0.17 microns. Variation in fiber diameter within each top (SD) is also an important characteristic. No differences ($P > 0.05$) were observed for 4 of the 9 tops between SD values from LS and PM. Five tops were different ($P < 0.05$), with values ranging from -0.28 to 0.05 microns.

Key words: wool, fiber diameter, Laserscan.

Introduction

Average fiber diameter and variability of animal fibers are two of the most important characteristics used in the classification, evaluation, marketing and spinning of the fiber (Pohle, 1975; Whiteley and Jackson, 1982). Fiber diameter is the major factor that determines relative value in the marketing of wool. Other characteristics, such as staple length, are also important but diameter is the primary characteristic when determining value. All wool is sold according to either an estimated diameter or measured diameter of the lot. Improvements in processing equipment have necessitated the accurate measurement of diameter and variation in diameter. Objective measurement of fiber diameter and corresponding variation in diameter is becoming the preferred method of classifying wools according to their respective diameter. A producer that knows the AFD and variation in the clip of wool he is trying to market has information allowing him to value his product accordingly. Market reports are readily available that provide information concerning the respective value of wools of different diameters.

Information on wool characteristics of individual sheep is also valuable to the sheep breeder for use in selection programs. Since heritability of fiber fineness is quite high, rapid change in the AFD of a flock over a generation interval is possible; or, average diameter of the flock can be maintained at a constant value, within environmental limitations, provided it is measured correctly. Accuracy is important since the heritability of any trait decreases as the accuracy of measurement decreases thus slowing the response to selection.

The development of rapid, accurate and repeatable standardized methods of sampling and testing has allowed

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improvement in the ability to describe various quality characteristics of animal fibers (Pohle, 1961). Objective measurements of grade have been used for some years using micrometer (μm) to describe fiber diameter and variability specifications when marketing and evaluating wool top. In recent years, AFD of raw greasy wool (scoured before testing) has been used for describing, marketing and evaluating wool on an "objective micrometer basis" worldwide. Fiber diameter is recognized as the most important physical attribute of raw apparel wool in determining the type of fabric into which it may be processed. Measurement of fiber diameter continues to be the most labor-intensive, time-consuming effort of describing wool. Since the wool industry needs accurate, up-to-date information, precise and fast methods of objective measurements must be developed. Numerous attempts have been made to increase the speed with which animal fibers may be measured (ASTM, 1996a; IWTO, 1989a). These procedures have saved time; however, they lack the ability to measure distribution of AFD (Rottenbury, 1992; Hansford, 1992; Lamb, 1992).

The PM has been widely used since the 1920s for measuring fiber diameter and distribution of diameter and is still utilized as the standard reference method (Mennerich, 1936; ASTM, 1996b; IWTO, 1989b). This method is subject to human error, is tedious, time-consuming and expensive. Trained technicians can measure approximately 200 fibers in a 15-minute time frame. Two new systems for the rapid measurement of fiber diameter and variability in diameter have recently been introduced. The Sirolan-Laserscan (LS), developed by Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia (Baird and Barry, 1993), uses laser technology to rapidly measure fiber diameter and variability. The LS has been approved by IWTO as an authorized test method (IWTO, 1993). Another instrument, the Optical Fiber Diameter Analyzer (OFDA), marketed by BSC Electronics Pty Ltd (Baxter et al., 1991) uses image analysis techniques to measure fiber diameter. This system has also been approved by IWTO as an authorized test method (IWTO, 1995).

This study was initiated to evaluate the performance of the Sirolan-Laserscan for measuring fiber diameter and variability of diameter of wool top compared to the projection microscope method.

Materials and Methods

A Sirolan-Laserscan was leased from CSIRO for evaluation in the U.S. and based at the wool laboratory at the University of Wyoming in Laramie. The technology had not yet been granted IWTO Standard Test Method status although a test method under examination (TME) was in place. Data provided from interlaboratory testing of this instrument will provide a portion of the information necessary for writing an acceptable ASTM standard test method for the LS. Subsequently, this instrument was imported to evaluate it under U.S. conditions and with types of wools produced in the U.S, providing the necessary data for the ASTM method.

The Sirolan-Laserscan was used to measure the average fiber diameter (AFD) and standard deviation (SD) of wool top snippets (2 mm in length) using the protocol outlined in the TME (IWTO, 1993). The LS was calibrated using 8 1993 Interwoollabs IH tops and validated using 12 1985 and 1989 IH tops that had been measured by projection microscope. Calibration and validation of the instrument is crucial to its subsequent performance. Interwoollabs acquires a large stock of wool tops referred to as standards of calibration identified by the letters IH. For a given year, a complete series is composed of 8 samples covering a broad spectrum of fineness categories. Laboratories throughout the world calibrate their equipment using these tops and then measure round trial samples sent out by Interwoollabs. The organization's function is to achieve and maintain harmonization among member laboratories with regard to the test methods for mean fiber diameter of wool by means of the airflow apparatus and the projection microscope.

There have been several upgrades to the calibration procedure of the LS in the past several years that have improved the accuracy of the instrument, especially in the area of measurement of SD.

An interlaboratory test of the instrument was designed to evaluate the LS's performance in different labs around the United States. This article reports on the measurement of wool tops by the laboratories involved in the study.

The wool tops utilized in this study had been measured by both university and commercial fiber labs around the U.S. in round trials conducted by Yocom-McColl Testing Labs Inc. (McColl, 1993). The tops were measured using the standard ASTM PM method (ASTM, 1996b). These tops were selected for inclusion in this evaluation because they were the most uniform in diameter as indicated by the data obtained from the round trials. Because the objective of this project was to compare how well the LS measured the AFD of wool tops compared to the PM, it was imperative that the samples being measured were as uniform in diameter as possible. Laboratories participating in earlier round trials, conducted by Yocom-McColl, measured 800 to 1,200 fibers per sample, giving a 95% confidence interval of ± 0.4μm to ± 0.5μm for the top samples measured. Tops that are coarse, AFD greater than 26 microns, have wider confidence intervals because of the inherent fiber to fiber variability in diameter that accompanies wools that are above 26 microns in AFD. Measuring more fibers provides smaller confidence intervals but increases the time necessary to measure the samples. The LS is designed to provide a confidence interval of ± 0.2μm for tops under 26 μm and ± 0.3μm for tops over 26 μm. The confidence intervals provided by PM and LS need to be kept in mind when comparing the measurements provided by the two methods.

Seven laboratories participated in this part of the study: three university labs (Montana State University, Bozeman; Texas A&M University, San Angelo; University of Wyoming, Laramie); three commercial labs (Burlington Industries quality control lab; Santee

River Combing quality control lab; Yocom-McColl Testing Labs, Inc.); and the CSIRO Division of Wool Technology lab (Ryde, Australia). The LS was transported to each laboratory in the U.S. and set up and the validation tops were used to check the calibration. Whenever the values obtained from the validation samples were different from their designated values, a new calibration was performed. Twenty-five top samples were divided in half, providing 50 top samples which were randomly numbered and sent to each lab for measurement. The laboratories then measured three subsamples from each top, providing six measurements for each of the 25 tops. Nine tops were selected for inclusion in the current analysis because they were the most uniform in diameter (lowest SD) according to round trial data, as mentioned earlier. Sixteen tops were rejected because of excess variability along their lengths. The nine tops selected were sent to the CSIRO lab for measurement on their LS. The tops used in this study ranged from 18.9 µm to 31.6 µm in AFD.

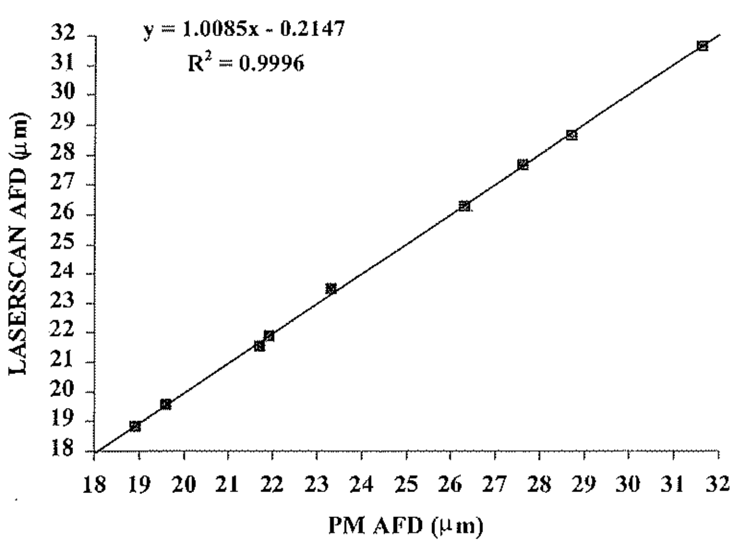
Differences between LS and PM measurements of the 9 top samples were compared using T-tests on means pooled among laboratories (Steel and Torrie, 1980) using the GLM procedures of SAS (SAS, 1992). Simple linear regression analyses were performed using the REG procedure of SAS. The AFD and SD differences between the LS and PM were plotted against the PM AFD and SD values to estimate possible biases of the LS measurements compared to those from the PM.

Table 1. Comparison of average fiber diameter (AFD, µm) and standard deviation (SD, µm) of wool tops by projection microscope (PM) and Sirolan-Laserscan (LS).

	PM (ASTM)		LS (IWTO)		Difference (LS - PM)	
Top	AFD	SD	AFD	SD	AFD	SD
1	18.90	3.67	18.83	3.58	-0.07	-0.09[a]
2	19.60	4.13	19.56	4.17	-0.04	0.04
3	21.70	4.75	21.53	4.67	-0.17[a]	-0.08[a]
4	21.90	4.58	21.86	4.56	-0.04	0.02
5	23.30	5.43	23.48	5.44	0.18[a]	0.01
6	26.30	6.17	26.29	6.12	-0.01	-0.05
7	27.60	6.56	27.68	6.33	0.08	-0.23[a]
8	28.70	7.11	28.66	6.97	-0.04	-0.14[a]
9	31.60	8.28	31.64	7.80	0.04	-0.28[a]

[a] Means in the same column with different superscript differ ($P < 0.05$).

Figure 1. Relationship between average fiber diameter (AFD, µm) measured with the Laserscan and projection microscope.



Results and Discussion

The overall difference in AFD between LS and PM was -0.009µm. The difference between SD was -0.09µm. Table 1 shows the PM diameters and SD values for each of the 9 tops compared to the LS measurements averaged over the 7 laboratories. Two of the top diameter measurements were different ($P < 0.05$). Of the tops that were different, the magnitude of the differences (-0.17µm, 0.18 µm) are within the published 95% confidence limits for the LS (± 0.2µm). PM and LS SD measurements were different between 5 of the tops ($P < 0.05$). These differences are also within the confidence limits of the LS (± 0.3µm). The linear relationship between LS and PM AFD is depicted in Figure 1. A similar plot of SD is shown in Figure 2. A regression equation ($y = 1.0085 \times -0.2147$) using LS measurements to predict PM values had an $R^2 = 0.999$, indicating the LS to be an excellent predictor of PM.

Table 2 shows the AFD LS values for the 7 laboratories and the difference between the laboratory LS average and the PM average. Although differences were present ($P < 0.05$), their magnitudes were within the 95% confidence intervals established for the LS. Differences were also present ($P < 0.05$) for SD values. Regression plots of the differences in diameter and SD are shown in Figures 3 and 4. Figure 3 shows that there is no significant ($P > 0.05$) bias between LS measurements and PM measurements for mean fiber diameter. Figure 4 shows the relationship among differences in LS SD and PM SD. There is a small significant bias ($r^2 = 0.5726$, $P < 0.05$) in the SD measurement between the LS and PM. The LS SD values are smaller than the SD values obtained by PM.

Implications

For wool tops the Sirolan-Laserscan produced measurements of fiber diameter that were not different than those produced by the PM. The LS is much faster than the PM method and reduces the number of personnel needed to measure samples. This reduction in time and personnel has already reduced the cost of commercial testing (side samples), allowing for increased individual animal testing and a reduction in the time needed to measure sale lots of wool. This technology will benefit both the producer and processors.

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Figure 2. Relationship between the standard deviations of fiber diameter (SD, μm) measured with the Laserscan and projection microscope.

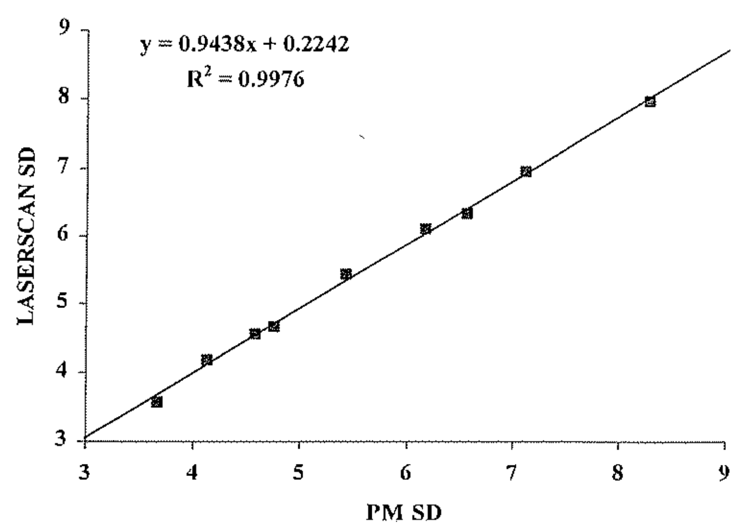

Table 2. Comparison between laboratories of average fiber diameter (AFD, μm) and standard deviation (SD, μm) of wool tops by projection microscope (PM) or Sirolan-Laserscan (LS).

	Lab						
Item	**A**	**B**	**C**	**D**	**E**	**F**	**G**
LS AFD	24.58	24.47	24.20	24.24	24.47	24.46	24.32
SD	5.51	5.55	5.51	5.47	5.63	5.59	5.49
Difference (LS - PM):							
AFD	0.18[a]	0.07	-0.20[a]	-0.16[a]	0.07	0.06	-0.08
SD	-0.12[a]	-0.08[a]	-0.12[a]	-0.16[a]	0.00	-0.04	-0.14[a]

[a] Means in the same row with different superscript differ ($P < 0.05$).

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Figure 3. Relationship between projection microscope (PM) and Laserscan (LS) average fiber diameter (AFD) difference (LS - PM, µm) and PM AFD.

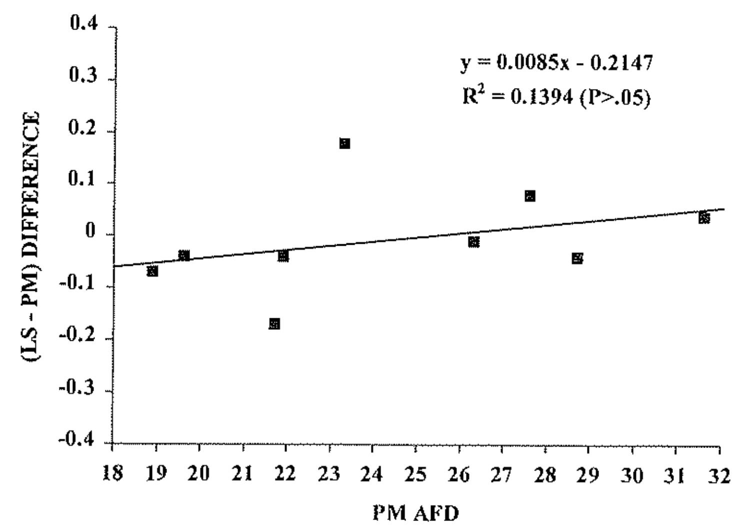
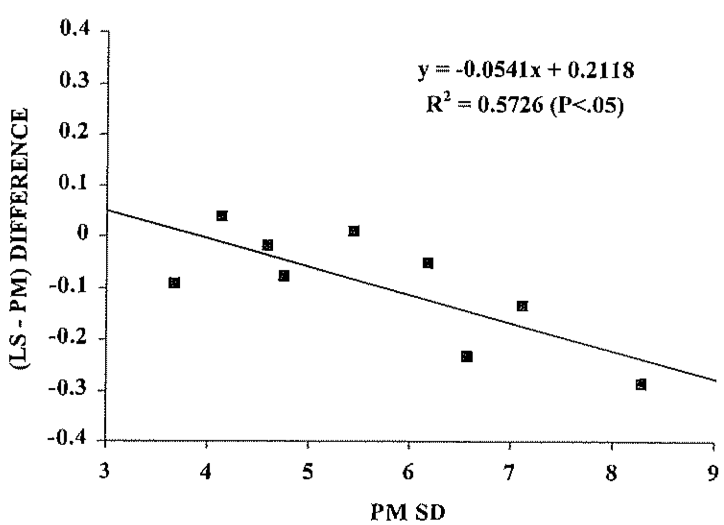


Figure 4. Relationship between projection microscope standard deviation (PM SD) and Laserscan standard deviation (LS SD) difference (LS SD - PM SD, µm) and PM SD.



Application of Embryo Transfer for the Improvement of Multiple Rearing Ability in Medium Wool Merino Ewes

S.W.P. Cloete[1,2], F.E. van Niekerk[3] and J.M. Rust[3,4]

Summary

Medium wool Merino ewes rearing less than 5 lambs over 5 lambing opportunities acted as donors in an embryo transfer (ET) program in 1990 and 1991. Ewes (n = 28) were 6.5 years of age with a mean performance (± standard deviation [SD]) of 1.33 ± 0.15 lambs reared/joining. A total of 2.9 ± 2.5 lambs were produced by ET and natural mating per donor, ranging from 0 to 10, with 46% of the donors producing less than 2 offspring. Ewe progeny from these ewes (n = 28; i.e., 1.0 per donor ewe) were evaluated against comparable ewes born in a divergent selection experiment for ewe multiple rearing ability during 1993 to 1997. These lines were selected from the same base population since 1986. In the high (+) line, ram and ewe replacements were mostly descended from dams that reared more than one lamb per joining. Progeny of ewes that reared less than one lamb per joining were preferred in the low (-) line. Expressed relative to mean (± SE) - line performance, total number of lambs reared over 4 lambing opportunities in the ET and + lines were improved ($P < 0.05$) by 33.3 and 29.5%, respectively (4.52 ± 0.31 and 4.39 ± 0.31 vs. 3.39 ± 0.28). Lambs reared by ET and + line ewes were respectively 14.4 and 12.5% heavier at weaning than - line contemporaries (23.8 ± 0.4 and 23.4 ± 0.5 vs. 20.8 ± 0.4 kg). There was a suggestion ($P = 0.13$) that total greasy fleece weight over 5 shearings in the ET and + lines could be impaired relative to the - line (25.0 ± 0.8 and 25.5 ± 0.8 vs. 27.1 ± 0.7 kg, respectively). There was also a suggestion ($Chi^2 = 2.37$; $P = 0.12$; df = 1) that a higher proportion of - line ewes (28/33 = 0.848) was available after four lambings compared to the + line (23/35 = 0.657). The latter tendencies may be associated with stress placed on ET and + line ewes by their higher reproduction rate. The multiple rearing ability of Merino ewes could thus be elevated to levels obtained after 6 to 7 years of selection by using ET on donors screened from a larger population.

Key words: embryo transfer, reproduction, selective breeding.

Introduction

Multiple ovulation and embryo transfer (ET) in livestock is seen as a useful tool to increase selection intensity on the female side (Rathie, 1982). This technique may result in genetic gains of 50 to 100% faster than by conventional means in sheep and beef cattle (Smith, 1988). It is also useful to enhance sex-limited traits with limited genetic variation (such as reproduction rate of sheep) by increasing the number of progeny produced by proven dams (Lang et al., 1982; Sakul et al., 1993).

Despite its obvious advantages with regard to the enhancement of genetic progress (Smith, 1988), industry acceptance of the concept of ET remains low (Bindon, 1988; Wuliji et al., 1995). Results of applied ET programs where its potential has been demonstrated are therefore scarce in the literature. It has recently been applied for the reduction of fiber diameter in a flock of ultrafine Merino sheep in New Zealand (Wuliji et al., 1995).

Mutton production is becoming increasingly important in South Africa (Laas, 1995). The South African Merino is reputed to have a poor reproductive performance, the mean number of lambs reared per ewe joined averaging between 0.70 and

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0.88 (Heydenrych, 1975; Olivier, 1982; Cloete and Heydenrych, 1986; Fourie and Cloete, 1993).

Against this background we conducted an ET program with ewes screened on the basis of their prolificacy from South African medium wool Merino flocks as donors. The result of the increased selection intensity obtained from ET was evaluated against production levels in Merino lines divergently selected for ewe multiple rearing ability since 1986 (Cloete et al., 1998).

Material and Methods

Selection and Treatment of Donor and Recipient Ewes

Donor ewes were screened from the Tygerhoek and Langgewens medium wool Merino flocks, comprising of approximately 550 and 220 breeding ewes respectively. The ewes at Tygerhoek belonged to a clean fleece weight selection line, a wider secondary-to-primary wool follicle ratio line, and a unselected Control group (Heydenrych et al., 1984). The Langgewens flock consisted of two lines that were divergently selected for ewe multiple rearing ability (Cloete and Durand, 1994). The ewes included in this study were born before selection commenced in 1987. In total, 255 ewes that were cast for age at 6.5 years were available in 1990 and 1991. The mean (± SD) number of lambs reared per joining over five lambing opportunities was 0.80 ± 0.33 across all these ewes. Ewes (n = 28) that successfully reared more than one lamb per joining over a 5-year reproductive life qualified for ET. The mean number (± SD) of lambs reared per joining over a 5-year reproductive life was 1.33 ± 0.15 for these ewes. Recipients were two-tooth ewes not selected as replacements in other flocks. Donor ewes and breeding rams were maintained indoors at the Welgevallen experimental farm of the University of Stellenbosch (Matieland, South Africa) during October through November, 1990 and 1991. They received a 1-to-1 mixture of oat hay and lucerne hay ad libitum. This mixture was supplemented with approximately 400 g of a 2-to-1 mixture of oat and lupin grain head^{-1} day^{-1}. Recipient ewes were kept outdoors on cement floor paddocks with a shade roof. They received the same roughage mixture, supplemented with approximately 300 g oat grain head^{-1} day^{-1}.

Estrus was synchronized using intravaginal Ovakron (registered trademark of Centaur) sponges containing 18 mg fluogestone acetate. Two donors and 12 recipients were prepared per day, for three days a week. The superovulation program of the donors consisted of a total dose of 18 mg equine FSH (Elsden and Associates, USA), administered as described in Table 1. Recipient ewes were treated as described in Table 1. Teaser rams were used for six-hour estrus detection in both groups. The first 11 donor ewes were mated to 4 rams selected on the basis of maternal rearing performance (Cloete and Durand, 1994). The dams of these rams reared 1.58 ± 0.29 lambs per joining over at least 4 lambing opportunities. They were selected from a

Table 1. Treatment of donor and recipient ewes in the embryo transfer program.

Day	Time	Action taken with Donor Ewes	Action taken with Recipient Ewes
0	16:00	Ovakron[a] sponges inserted	Ovakron[a] sponges inserted
11	07:00	4 mg Equine FSH[b] intramuscular	–
	19:00	3 mg Equine FSH[b] intramuscular	–
12	07:00	3 mg Equine FSH[b] intramuscular	–
	19:00	2 mg Equine FSH[b] intramuscular	–
13	07:00	2 mg Equine FSH[b] intramuscular	Sponges withdrawn, 1 mL Lutalyse[c] and 300 I.U. Pregnant Mare Serum[d] intramuscular
	19:00	Sponges withdrawn, 1 mL Lutalyse[c] and 2 mg Equine FSH[b] intramuscular	–
14	07:00	1 mg Equine FSH[b] intramuscular	–
	19:00	1 mL Receptal[e] and 1 mg Equine FSH[b] intramuscular	–
15	–	Mating or laparoscopic A.I.	–
20	07:00	Flushing of uterine horns	Transfer of embryos
27	16:00	1 mL Lutalyse[c] intramuscular	–

[a] Ovakron® sponges (containing 18 mg Fluogestone acetate) – registered trademark of Centaur.
[b] Equine FSH – Elsden & Associates, USA.
[c] Lutalyse® – registered trademark of Upjohn.
[d] Pregnant Mare Serum – Upjohn.
[e] Receptal® – registered trademark of Hoechst Agvet.

group of 192 rams, with an average maternal performance of 0.98 ± 0.34 lambs reared per joining. The rest of the ewes were laparoscopically artificially inseminated (using fresh electro-ejaculated semen from the same rams) 40 hours following the first observed estrus (Moore, 1982). After flushing, the donor ewes were injected with 2 mL of Lutalyse (registered trademark of Upjohn) to avoid multiple pregnancies from retained embryos.

Both horns of the uterus of donors were individually flushed 7 days after mating with phosphate buffered saline, containing 5% fetal calf serum, after mid-ventral laparotomy (Hunter et al., 1955). This procedure was carried out under general anaesthesia. The flushing medium was kept at 37 °C in a temperature regulated water bath. Recipient ewes received 1 to 2 embryos each, after being tranquilized and treated with local anaesthesia. Laparoscopy was used to secure a uterine horn, which was pulled through a small incision in the abdominal wall. Embryos were deposited close to the utero-tubal junction, using a Jacksons Tomcat catheter inserted through the uterine wall, previously punctured by a blunt object (Killeen, 1982). Embryos were deposited ipsilateral to the corpus luteum. The identity of the donor and recipient, as well as the number of embryos recovered and transferred, were recorded. Following the ET program, donor ewes were joined in single sire groups with the rams used during the program. Both donors and recipients were kept in a single flock at the Elsenburg Agricultural Center during the pregnancy and lactation period. Lambs were identified with their dams at birth.

Treatment of the Breeding Flock

Ewe progeny of the ET program was run in a single flock with two other lines divergently selected from the same base population for maternal multiple rearing ability since 1986 (Cloete and Durand, 1994; Cloete et al., 1998). Ewe and ram progeny descended from dams that reared more lambs than they had lambing opportunities were preferred as replacements in the high (+) line. Progeny of dams that reared fewer lambs than they had lambing opportunities (i.e., failed to rear a lamb at least once) were preferred in the low (-) line. Depending on replacement requirements and average reproduction rate, progeny of ewes that reared one lamb per lambing opportunity was occasionally accepted in both lines. All ewes were joined annually in single sire groups within lines to rams that were tested fertile and dexterous during 1993 through 1997. Joining took place during January through February each year, on irrigated kikuyu paddocks. The same facility was used during lambing in June through July. The breeding flock was maintained on dry-land lucerne and medic pastures for the remainder of the year, with the occasional use of an oat fodder crop.

Recordings

Progeny born as the result of ET and natural mating were recorded per donor ewe. Complete annual reproduction (1993 to 1997) and greasy wool production (1992 to 1997) figures of individual breeding ewes were kept. Reproduction figures were accumulated to give total lamb output over 4 lambing opportunities (ages 2 to 5 years). Total greasy wool production from 18 months to 5 years of age, as well as live weight at the 4.5 years joining, were also determined. Prior to lambing in 1997 a midside wool sample was clipped from all ewes present in the flock and analyzed for clean yield, staple length, staple strength, fiber diameter and the coefficient of variation of fiber diameter. Lambs were identified with their dams and weighed within 12 hours of birth. Lamb mortality prior to weaning and weaning weight were recorded for individual lambs.

Statistical Analysis

Means, ranges and standard deviations were calculated for number of embryos recovered, lambs born through ET and natural mating as well as total number of lambs born per donor ewe. One-way analysis of variance procedures were used to compare the three lines for total and mean lamb output (numbers of lambs born or weaned over four years), total greasy wool production, mature live weight and wool quality traits. Lamb birth and weaning weight were analyzed by least squares procedures (Harvey, 1990), the fixed model containing the effects of line, sex (male, female), birth type (single, multiple), lambing year (1993 to 1997) and two-way interactions.

Results

The ET Program

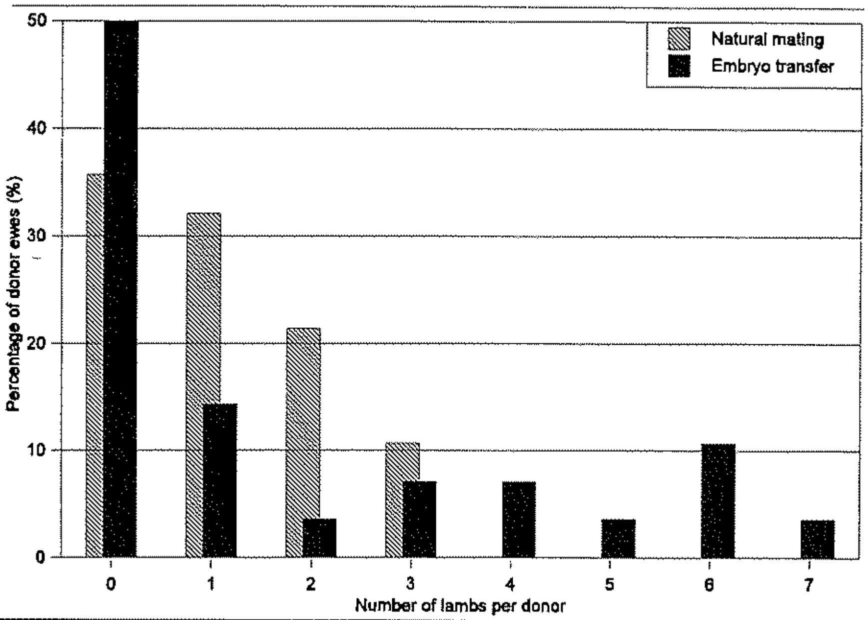
The mean (± SD) number of embryos recovered per donor was 3.6 ± 4.3, with a range between 0 and 13. In 32% of the donors no embryos were recovered. The ET program resulted in a mean number of 1.8 ± 2.4 lambs being born per donor, with a range of 0 to 7 (Figure 1). Lambs born as a percentage of embryos transferred were 50%. Natural mating after surgery resulted in a further 1.1 ± 1.0 lambs being born per donor, with a range between 0 and 3 (Figure 1). In 36% of donors no progeny was produced through natural mating after surgery. In total, 2.9 ± 2.5 lambs were produced per donor, with a range of 0 to 10. Only 16% of donors failed to produce any progeny through ET and natural mating combined. A total of 46% of the donors produced more than two offspring.

Ewe Survival and Production Parameters

Of the 33 - line ewes selected as replacements for joining in 1993 and 1994, 28 were present at the weaning of their lambs at 5.5 years (a proportion of 0.848). There was a suggestion of higher rates of attrition in the + line (23/35 = 0.657; Chi^2 = 2.37; P = 0.12; df = 1). However, no significant line differences were observed. In total 5 ewes (2 each in the + and - lines, 1 in the ET line) succumbed to ketosis and hypothermia. Seven ewes (4 in the + line, 2 in the - line, 1 in the ET line) were recorded missing between lambing and the subsequent joining. Plant poisoning was recorded in 2 ewes, one each in the + and ET lines. Two ewes were culled from the ET line due to udder defects and one from the - line because of a broken mouth. The remaining five + line ewes died under unnatural circumstances; four when the flock was continuously harassed by stray dogs during 1995 (claiming 52 out of a total of 301 lambs), while one was killed by stock thieves in 1997.

Selection differentials derived from maternal performance in ET line ewes amounted to 1.8 phenotypic standard deviations on the male side and 1.6 phenotypic deviations on the female side. In response, total lamb output in the ET line was increased to the same levels as was observed in the + line (Table 2). Total lamb output over 4 years in the ET and + lines was improved (P < 0.05) relative to the - line. Expressed relative to mean - line performance, the differences amounted to 19.0 and 18.1%, respectively, for total number of lambs born in the ET and + lines. The corresponding differences for total number of lambs reared were 33.2 and 29.5%, respectively. Expressed per lambing opportunity, number of lambs reared averaged approximately 1.1 in the ET and + lines compared to 0.85 in the - line (Table 2).

Figure 1. Percentage distribution of number of lambs born per donor, either through natural mating or embryo transfer.



After least squares adjustment for a higher birth rate, lambs given birth to by ET and + line ewes were heavier (P < 0.05) at birth than - line contemporaries (Table 2). Lamb survival was not compromised in the + and ET lines, despite a higher birth rate. Progeny of the ET and + lines were heavier at weaning than - line contemporaries. Expressed relative to mean - line performance, the differences in weaning weight amounted to 14.4 and 12.5%, respectively, for the ET and + line lambs.

Total wool production and mature live weight did not differ between lines, but there was a suggestion (P = 0.13) for - line ewes to produce slightly more wool than the other two lines (Table 3). This tendency was reduced to insignificance (P = 0.31) by the inclusion of total number of lambs reared as a linear covariable in the model used to analyze total greasy wool production. Wool quality traits were correspondingly independent of genetic line.

Discussion

Results of the ET Program

Recently, Bindon (1988) conceded that it is not yet possible to guarantee

Table 2. Reproductive performance (mean ± SE) of Merino ewes born as progeny of donor ewes (ET line), or in the high (+) or low (-) selection lines and their lambs. Ewe reproduction was accumulated over four lambings opportunities.

Parameters	Line		
	- line	**+ line**	**ET line**
Ewe reproduction over four lambings (2 to 5 years):			
Ewes available	28	23	23
Total number of lambs born	$4.75^b \pm 0.28$	$5.61^a \pm 0.31$	$5.65^a \pm 0.31$
Total number of lambs reared	$3.39^b \pm 0.28$	$4.39^a \pm 0.31$	$4.52^a \pm 0.31$
Mean number of lambs born	$1.19^b \pm 0.07$	$1.40^a \pm 0.08$	$1.41^a \pm 0.08$
Mean number of lambs reared	$0.85^b \pm 0.07$	$1.10^a \pm 0.08$	$1.13^a \pm 0.08$
Lamb performance:			
Number of lambs born	133	129	130
Birth weight, kg	$3.92^b \pm 0.06$	$4.18^a \pm 0.07$	$4.27^a \pm 0.06$
Survival per lamb born	0.714	0.783	0.800
Weaning weight, kg	$20.8^b \pm 0.4$	$23.4^a \pm 0.5$	$23.8^a \pm 0.4$

[a,b] Means with different superscripts differ (P < 0.05) in rows.

a useful number of embryos from a given donor, despite continued research. The number of ET progeny produced per donor (1.8) in our study is somewhat lower than the figure of 2.7 obtained by Hanrahan and Quirke (1982), while it accorded with the figure of 1.4 reported by Boundy et al. (1985). Greaney et al. (1985) similarly reported that the number of ET lambs born per donor averaged 1.58 out of season and 0.98 in season, while Larsson et al. (1991) reported a total of 43 ET lambs being born out of 25 donor ewes (1.7 lambs per ewe). The percentage of 50% donor ewes failing to produce any progeny through ET in this study tends to be higher than literature results, including corresponding figures of 22% (Hanrahan and Quirke, 1982), 32 to 39% (Kelly et al., 1983) and 30% (Boundey et al., 1985).

The number of lambs born through natural mating in our study was somewhat lower than reported in the literature (Boundy et al., 1985; Hanrahan and Quirke, 1982), where more prolific sheep breeds like the Texel and Finnish Landrace were used. The percentage of 36% of donor ewes that failed to produce any progeny with natural mating after surgery nevertheless accorded with figures of 33% (Hanrahan and Quirke, 1982) and 38 to 44% (Kelly et al., 1983), while it was higher than the figure of 10% reported by Boundy et al. (1985). The figure of 2.9 lambs being born per donor ewe was within the range of that reported in the literature (Boundy et al., 1985; Hanrahan and Quirke, 1982; Kelly et al., 1983; Wuliji et al., 1995), ranging from 2.7 to 4.3. An annual lamb production of 2.5 lambs reared per donor was similarly estimated from a study by Sakul et al. (1993). This study involved the collection, cryopreservation and transfer of embryos from four closed lines of Targhee sheep.

Ewe Performance

Mean reproduction figures found in the - line accorded with those previously reported for South African Merino sheep (Heydenrych, 1975; Olivier, 1982; Cloete and Heydenrych, 1986; Fourie and Cloete, 1993). The benefit of purposeful selection for maternal multiple rearing ability was evident from the enhanced performance of + and ET line ewes, despite a relatively low heritability of 0.14 for lambs reared per ewe joined in the Tygerhoek population (Cloete, 1986). From Table 1, it could be calculated that the weight of lamb reared by ewes in these lines over four lambings, amounted to respectively 102.8 (+ line) and 107.6 (ET line) kg, as compared to 70.6 kg in the - line. This response confirms observations previously reported for a similar selection experiment at the Langgewens experimental site (Cloete and Durand, 1994). It also accorded with findings previously reported in Australia (Atkins, 1980).

The higher weaning weight of lambs produced in the + and ET lines warrants further attention. In theory, it could be the result of direct additive genetic effects, maternal additive genetic effects or maternal permanent environmental effects. Since weaning weight in beef cattle were genetically closely associated with maternal milk production (Meyer et al., 1994), it may be hypothesized that the selection in + and ET line ewes possibly enhanced their ability to provide nourishment for their offspring. Depending on the magnitude of direct additive genetic variation for weaning weight, the genetic effect of sires used in the breeding program could also have contributed to the variation in lamb weaning weight. Although the random effect of service sire had a significant influence on ewe reproduction per lambing, its effect on breeding values of ewes for reproduction rate was minimal (Burfening and Davis, 1996). Further research is, however, required to elucidate these topics.

Table 3. Total wool production, mature live weight and qualitative wool traits of the progeny of donor ewes (ET line) or in the high (+) or low (-) selection lines.

	Line		
Parameters	- line	+ line	ET line
Wool production over five lambings (16 months to 5 years):			
Ewes available	28	23	23
Total greasy fleece weight, kg	27.1 ± 0.7	25.5 ± 0.8	25.0 ± 0.8
Mature live weight, kg	56.4 ± 1.6	55.1 ± 1.8	53.4 ± 1.8
Wool quality traits in ewes present at lambing in 1997:			
Ewes available	28	22	19
Clean yield, %	76.2 ± 0.6	75.1 ± 0.7	76.0 ± 0.8
Staple length, mm	91.4 ± 2.8	87.2 ± 3.2	91.4 ± 3.4
Staple strength, N/ktex	50.9 ± 2.3	51.9 ± 2.6	55.2 ± 2.8
Fiber diameter, µm	23.7 ± 0.4	24.0 ± 0.4	24.1 ± 0.5
CV[a] of fiber diameter, %	18.2 ± 0.3	18.7 ± 0.3	18.1 ± 0.4

[a] CV = coefficient of variation.

No conclusive detrimental effect of selection was demonstrated for wool traits and live weight. It stands to reason that wool production could be impaired in the + and ET lines by the increased stress of particularly lactation (Heydenrych, 1975). The tendency (P = 0.13) towards a line difference for total greasy wool production was reduced to insignificance by accounting for the higher multiple rearing rate of + line and ET ewes by analysis of covariance. This observation lends support to the contention that wool production in the latter lines was compromised because of the increased stress of reproduction. The risk associated with a higher reproduction rate could also impact negatively on the longevity of selected ewes. Findings in this regard were inconclusive in the present study.

The increased selection intensity due to ET was clear from the results. It enabled us to produce 28 ewe progeny from 28 donor ewes, producing at a mean performance level similar to that achieved after 6 to 7 years (± 2 generations) of within flock selection in the + line. Similar benefits were demonstrated in a study where the reduction of hogget fiber diameter was the primary objective (Wuliji et al., 1995). Haughey (1983) also utilized ET to increase the numbers of replacement ewes in a study that demonstrated selection responses in ewe rearing ability.

Conclusions

Multiple ovulation and ET enabled us to produce one replacement ewe per donor ewe treated. The program could be regarded as successful, since it enhanced this figure above the approximately 0.5 ewe progeny per donor expected with natural mating. Since the theoretic advantages of ET are usually calculated on the assumption that 5 to 10 progeny are available per donor (Toro et al., 1988) it must be conceded that this potential was not realized. The high variability of success, and costs associated with ET, impacts negatively upon its application in industry (Bindon, 1988; Kelly et al., 1983; Wuliji et al., 1995). From a breeding perspective the benefit of ET was clear. A response brought about by 6 to 7 years of within-flock selection, was achieved within two seasons. Given that even faster progress may be achieved by innovations such as juvenile ET (Smith, 1988; Wray and Goddard, 1994), the potential of the technology is evident. From a breeding perspective, the judicious identification of donors in such programs is of paramount importance to ascertain progress in the desired direction.

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Influence of Cull Ewe Body Condition on Carcass Composition[1]

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Summary

The relationship of body condition score (BCS) and carcass composition of mature western white-faced range ewes was evaluated. Sixty ewes were selected and allocated to BCS groups of high condition (HC), medium condition (MC) and low condition (LC). HC ewes had a BCS score greater than 3.5, MC ewes had a BCS score of 2.5 to 3.5 and LC ewes a BCS score of less than 2.5. Average BCS at slaughter was 4.08 (HC), 2.70 (MC) and 1.48 (LC). The MC ewes averaged 4.3 kg heavier at slaughter than the LC ewes, and the HC ewes averaged 5.6 kg heavier than the MC ewes. Total lean was heavier ($P < 0.05$) for HC ewes than LC ewes but not different ($P > 0.05$) for HC compared to MC ewes or for MC compared to LC ewes. When expressed as a percent of cold carcass weight, LC ewes were leaner ($P < 0.05$) than MC ewes ($P < 0.05$) and LC ewes and MC ewes were leaner than HC ewes ($P < 0.05$). Boneless lean trim from HC ewes was higher in fat and lower in moisture and protein than MC and LC ewes ($P < 0.05$), and boneless lean trim from MC ewes was higher in fat and lower in moisture than LC ewes ($P < 0.05$). Although the differences in chemical composition were smaller in rib, loin and leg cubes used for kabobs, the trends and levels of significance were similar to those in boneless lean trim. The implications of these differences in carcass composition of the BCS groups for the development of retail products from mutton are discussed.

Key words: cull ewe, body condition, carcass composition.

Introduction

Cull ewes have traditionally been viewed as a low value by-product of the sheep industry in the United States. However, mutton is considered an acceptable product among many Basque, Hispanic, Asian, Middle Eastern and North African populations. With some of these ethnic populations growing rapidly in the United States, there may be an increasing opportunity for value-added mutton products in this country.

Bass et al. (1977) reported that meat from cull ewes was a marketable product and had little taste difference compared to lamb when properly conditioned and processed. Griffin et al. (1992) found that foreign taste panelists from the above-mentioned regions rated mutton higher in flavor and overall acceptability than domestic panelists, and rated mutton similar to lamb. Bond et al. (1990) developed two summer sausage products from mutton with either 14.7 or 19.6% fat and compared them with a commercially-available summer sausage. When the mutton sausage with 14.7% fat was compared with the commercial sausage, 65 out of 100 taste testers preferred the mutton sausage. When the mutton sausage with 19.6% fat was compared with the commercial sausage, both were liked equally by the panelists. The mutton summer sausages were therefore liked as well as or better than a commercial summer sausage sold nationwide. Hand et al. (1993) also reported that it was feasible to profitably produce lower fat sausage products from cull ewes.

Chemical composition and weight of carcass components were determined in several early studies in New Zealand and Great Britain (Barton and Kirton, 1958; Ulyatt and Barton, 1963; Russel et al., 1969, 1971). Field et al. (1987) reported on the composition of cull western range ewes in the U.S., and indicated that ewes in "medium" body condition contained greater amounts of lean and less connective tissue than ewes in "poor" body condition. Olthoff and Dickerson (1989) reported that body weight alone was as reliable in predicting body fat content of cull ewes as weight combined with other external indicators of fatness. Sanson et al. (1993) agreed that body weight and body

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condition or fatness are highly correlated (r = 0.89), but body condition score accounted for more of the variation in percent fat in the empty body (R^2 = 0.95) than did body weight (R^2 = 0.84). The purpose of this study was to more clearly determine the effect of body condition on separable lean product yield from various carcass components and on retail product yield from cull ewe carcasses.

Materials and Methods

Approximately 150 cull western white-faced range ewes from 4 to 6 years of age were body condition scored, using scores of 1 (emaciated) to 5 (extreme fatness) as described by Russel et al. (1969). Sixty of the ewes were then allocated to 3 discrete groups on the basis of body condition score (BCS). Twenty ewes with a BCS of less than 2.5 were allocated to a low condition (LC) group, 20 with a BCS of 2.5 to 3.5 to a medium condition (MC) group and 20 with a BCS of greater than 3.5 to a high condition (HC) group. BCS values were agreed to by a panel of 3 scorers to the nearest half score (i.e., 1.5, 2.5, etc.). Average BCS for the 3 groups just prior to slaughter (Table 1) was 1.48 (LC), 2.70 (MC) and 4.08 (HC).

The cull ewes were slaughtered over a 2-month period. The HC ewes were fed alfalfa hay ad libitum to maintain body condition, and the MC ewes were fed 4.0 pound/head/day alfalfa hay during this period. LC ewes were maintained on 3.0 pound/head/day alfalfa hay and did not gain body weight from allocation to slaughter. Twenty-four hours before slaughter the ewes were weighed, assigned a final BCS and removed from feed but allowed access to water. The ewes were slaughtered in a USDA inspected meat plant (Est. 6004) in accordance with USDA regulations and normal commercial practices on the premises of the University of Nevada, Reno Agricultural Experiment Station.

Hot carcass weights were recorded after slaughter and the carcasses were placed in a cooler (-2 to 0 °C) for 24 hours or longer. Pre-trial comparisons of boneless yields indicated there was no advantage in hot-boning over processing at 24 hours. However, some carcasses hung in the cooler for over a week due to student labor availability during holidays. The average slaughter to processing period was slightly over 3 days for all 3 groups.

Chilled carcass weights were recorded upon removal from the cooler. Major whole muscles were knife separated from the rib, loin and leg regions of the intact carcass. Although only the leg and shoulder are listed in "Uniform Retail Meat Identity Standards" (NLSMB, 1995) for producing cubes for kabobs, it was decided to make cubes from the major muscles from the rib, loin and leg. Muscles included the major parts of the longissimus, gluteus medius, psoas major, quadriceps, tensor fasciae latae, biceps femoris, semitendinosus, semimembranosus, adductor and other closely associated minor muscles. All visible fat and connective tissue were removed from the muscles, which were cut into 2.5- to 3-cm cubes. The remainder of the carcass was then knife separated into lean, fat and bone components and weights recorded for each component. Kidney, pelvic and heart (KPH) fat was removed separately and its weight was recorded. The kidneys were also separated and weighed.

Boneless lean trim was ground through a 0.95-cm plate the first time. The cubes and ground mutton were thoroughly mixed before sampling. Duplicate aliquot samples were removed from the ground boneless trim and from the rib, loin and leg samples, labeled, vacuum packaged and placed in a freezer (-23 to -18 °C). The thawed samples were lyophilized (Virtis Freeze Drier, Gardner, NY) to a constant weight and moisture content was determined. Dried samples were then combined with dry ice and blended until thoroughly ground and mixed to prevent lipid loss (Kellaway, 1973). Duplicate 0.5 g samples were used for crude protein determination by the Kjeldahl N procedure (AOAC, 1984). Lipid content was determined by extraction procedures using 1:1 (v:v) mixture of chloroform and methanol (Perkins, 1975). Ash was calculated by difference.

The rib, loin and leg major muscle cubes were vacuum tumbled in a red wine based marinade to produce a Basque theme product. The marinade was used to improve tenderness and flavor. In addition, USDA regulations allow a 10% gain in cube weight which is advantageous to the processor. The

Table 1. Influence of ewe body condition group on least squares means and standard errors (SE) of carcass measurements.

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Live weight, kg	65.27[b]	1.90	69.54[b,c]	2.29	75.14[c]	2.42
Body condition score	1.48[b]	0.07	2.70[c]	0.07	4.08[d]	0.04
Fat thickness, cm	0.02[b]	0.01	0.38[c]	0.06	1.12[d]	0.16
Hot carcass weight, kg	27.28[b]	0.85	30.30[b]	0.90	38.71[c]	1.61
Cold carcass weight, kg	24.77[b]	0.74	27.87[b]	0.93	36.45[c]	1.52
Dressing percent[a]	41.80[b]	0.51	44.13[b]	1.46	51.68[c]	1.62
Cooler shrink, %	9.00[b]	1.09	8.08[b,c]	0.94	5.85[c]	0.62
Total lean weight, kg	15.67[b]	0.42	16.80[b,c]	0.70	18.23[c]	0.57
Boneless trim weight, kg	11.78[b]	0.43	12.64[b,c]	0.50	13.50[c]	0.45
Rib, loin and leg kabobs, kg	3.89[b]	0.15	4.16[b,c]	0.26	4.73[c]	0.20
Bone weight, kg	7.61	0.20	7.41	0.17	7.39	0.26
Trimmable fat weight, kg	0.94[b]	0.22	2.76[c]	0.43	8.40[d]	0.92
KPH fat weight, kg	0.32[b]	0.06	0.66[b]	0.13	2.08[c]	0.21
Kidney weight, kg	0.16	0.01	0.16	0.01	0.15	0.01
Cutting loss weight, kg	0.14	0.07	0.14	0.05	0.32	0.08

[a] Dressing percent was calculated on a hot carcass weight basis.
[b,c,d] Row means that do not have a common superscript letter differ ($P < 0.05$).

cubes were processed into skewered cubes for a kabob retail product that also included chunks of onion and bell pepper. The remaining boneless lean trim was processed into sausage products. Manufacturing procedures for mutton products are given in a companion paper (Ringkob et al., 1998) which appears on pages 185 to 190 of this journal.

The data were analyzed as a completely randomized design with body condition level (HC, MC, LC) as the main effects using GLM procedures of SAS (1988). Using least squares means procedure (SAS, 1988), the least significant difference procedure was used for means separation if a significant F-test was detected (Steele and Torrie, 1980).

Results and Discussion

Carcass

Carcass data are presented in Table 1. The three groups had over 1 unit difference in BCS between each group, and no overlap in BCS among groups. The MC ewes averaged approximately 4.3 kg heavier at slaughter than the LC ewes, and the HC ewes averaged 5.6 kg heavier that the MC ewes. Fat thickness over the loin increased ($P < 0.05$) with increasing condition score. Although hot and cold carcass weights were heavier and dressing percent was higher for MC ewes when compared to LC ewes, these differences were not significant ($P > 0.05$). Hot and cold carcass weights were heavier ($P < 0.05$) and dressing percentage was higher for HC ewes when compared to MC and LC ewes. The percent cooler shrink decreased as carcass fat content increased. However, only the LC group was different from the HC group ($P < 0.05$). Even though the percent cooler shrink decreased by over 3% from LC to HC there was only a 0.2 kg difference due to the inverse relationship between cooler shrink and carcass weight. Total lean weight, boneless trim weight and cubes for kabobs weight (rib, loin, leg) were different for the LC and HC groups ($P < 0.05$) due to weight differences among the BCS groups. However, there was no difference among groups when comparing bone and kidney weight. There was over 3 times as much trimmable and KPH fat for the HC group as compared to the MC group ($P < 0.05$).

When the carcass components are converted to a percent of the carcass as shown in Table 2, the HC group was different ($P < 0.05$) from both the LC and MC groups for all items. The major components (lean, bone, fat) on a percentage basis are different ($P < 0.05$) among all body condition groups (LC, MC, HC). These data agree with other studies (Callow, 1948; Ringkob et al., 1964; Field et al., 1987) in that with an increase in fatty tissue in the carcass there is a correlated increase in weight of the musculature but a decrease in the percent lean in the carcass. As shown in Tables 1 and 2, similar effects of body condition on boneless lean trim and rib, loin and leg cubes for kabob weights and percentages of the carcass were observed when comparing LC and MC to the HC group. When expressed as a percentage of carcass all BCS groups were different ($P < 0.05$) with trimmable fat being 3.48%, 9.70% and 22.29% of the carcass for the LC, MC and HC ewes, respectively.

Table 2. Influence of ewe body condition group on least square means and standard errors (SE) for percentage of cold carcass components.

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Total lean, %	63.46[a]	0.76	60.18[b]	1.21	50.57[c]	1.15
Boneless trim, %	47.54[a]	0.85	45.41[a]	1.13	37.46[b]	0.94
Rib, loin and leg kabobs, %	15.91[a]	0.71	14.77[a]	0.47	13.12[b]	0.49
Bone, %	30.89[a]	0.58	26.95[b]	0.81	20.63[c]	0.80
Trimmable fat, %	3.48[a]	0.69	9.70[b]	1.33	22.29[c]	1.44
KPH fat, %	1.23[a]	0.18	2.32[a]	0.44	5.65[b]	0.52
Kidney, %	0.70[a]	0.04	0.59[b]	0.03	0.43[c]	0.02

[a,b,c] Row means that do not have a common superscript letter differ ($P < 0.05$).

Table 3. Influence of ewe body condition group on least square means and standard errors (SE) for chemical composition of mutton and boneless trim (wet weight basis) for sausage.

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Moisture, %	71.33[a]	0.85	66.95[b]	0.80	62.66[c]	0.62
Chemical fat, %	9.86[a]	0.95	14.97[b]	0.98	20.23[c]	0.67
Crude protein, %	17.86[a]	0.29	17.64[a]	0.26	16.87[b]	0.19
Ash and error, %	0.95[a]	0.18	0.63[a]	0.14	0.44[b]	0.12

[a,b,c] Row means that do not have a common superscript letter differ ($p < 0.05$).

Proximate Analysis

BCS affected the percent moisture ($P < 0.05$), percent fat ($P < 0.05$) and percent protein ($p < 0.05$) in the boneless lean trim (Table 3). Carcasses from HC ewes were higher in percent fat and lower in percent moisture and percent protein than MC and LC ewes, and carcasses from MC ewes were higher in percent fat and lower in percent moisture and percent protein than carcasses from

LC ewes. Although the differences in chemical components were smaller in the rib, loin, and leg cubes for kabobs, as shown in Table 4, the trends for percent moisture and percent chemical fat and levels of significance were similar to those observed for boneless lean trim. This was due to trimming all visible fat.

The chemical analyses data for boneless trim and rib, loin and leg lean were calculated to actual component amounts, then combined to estimate chemical composition of the total carcass lean trim (Table 5). These data would be of interest to those using the total boneless lean trim in a carcass for a single product rather than from separate products as reported in this study. The data were statistically analyzed on an individual carcass basis for the chemical composition data of total boneless lean trim, and the effects of body condition on percent moisture and percent chemical fat are readily apparent among groups ($P < 0.05$).

Implications

The boneless lean trim from ewe carcasses in the MC body condition score group had a very similar fat content (14.97%) to the 14.7% fat content mutton summer sausage developed by Bond et al. (1990) that was preferred by 65 out of 100 taste testers over a commercially available summer sausage. The fat content (20.23%) of the HC boneless lean trim was slightly higher than the 19.6% fat mutton sausage that Bond et al. (1990) developed that was determined to be equally acceptable to a commercially available summer sausage. The boneless lean trim of LC ewes, at 9.86% fat, was determined to be too lean to produce an acceptable sausage product. The two options for using boneless lean trim from LC ewes are to either add a portion of the fatter trim back to the boneless trim to approach 15% fat content, or blend the boneless trim from HC ewes with that from LC ewes to produce a boneless lean trim that is approximately 15% fat content.

The rib, loin and leg cubes for kabobs from all 3 treatment groups are clearly low in fat content (3.60 to 7.09%). This suggests that these carcass components have the potential of being developed into a lower fat product that is desired by many of our current meat consumers.

For processors that are interested in using the total cull ewe carcass for a single sausage product, even the HC ewes at 16.84% fat would produce an acceptable product. The MC ewes at 12.76% fat and the LC ewes at 8.36% fat would require fat trim to be added to reach the 14.7% fat product produced by Bond et al. (1990).

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	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Moisture, %	76.24[a]	0.25	74.20[b]	0.46	72.51[c]	0.40
Chemical fat, %	3.60[a]	0.30	6.13[b]	0.44	7.09[b]	0.38
Crude protein, %	18.54[a]	0.16	18.97[a]	0.24	19.99[b]	0.24
Ash and error, %	1.60[a]	0.26	0.76[c]	0.20	0.52[b]	0.15

a,b,c Row means that do not have a common superscript letter differ ($p < 0.01$).

Table 5. Influence of ewe body condition group on least square means and standard errors (SE) for chemical composition of combined boneless trim with rib, loin, and leg cubes for kabobs (wet weight basis).

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Moisture, %	72.48[a]	0.71	68.76[b]	0.66	65.19[c]	0.56
Chemical fat, %	8.36[a]	0.80	12.76[b]	0.78	16.84[c]	0.58
Crude protein, %	18.03	0.23	17.98	0.21	17.68	0.15
Ash and error, %	1.13[a]	0.17	0.66[b]	0.13	0.46[b]	0.11

a,b,c Row means that do not have a common superscript letter differ ($p < 0.01$).

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Marketing Mutton as a Branded Product[1]

T.P. Ringkob[2,3], H.A. Glimp[2], L.B. Bruce[2], W.C. Lawler[2], R.F. Butler[2] and E.F. Cox[4]

Summary

The development and marketing of all-mutton products utilizing the entire carcass was the emphasis of this study. The boneless mutton, lean trim and cubes for kabobs, from the rib, loin and leg, produced by processing 60 whole carcasses from 4- to 6-year-old ewes (Glimp et al., 1998) were used in this project. After some preliminary collaboration between University of Nevada – Reno (Est. 6004) and a local supermarket chain's personnel, it was decided that sausage and cubes for kabobs had the greatest market potential. A theme, Basque style meats, was developed for identity and market promotion. Project and store personnel determined sheep projected a more positive image than mutton, therefore "sheep" was used in the ingredient list on the labels. Three of the four original products (smoked sausage, chorizo, cubes for kabobs) survived the preliminary testing. Dinner sausage, a fresh product, failed because of appearance due to premature color deterioration as determined by supermarket management. This information is important to marketing programs so that mistakes are not repeated. A small slaughter and processing plant could be price-competitive for ewes by producing the products utilized in this project. However, if value-added products such as shish kabob are restricted and a distributor collects a fee, the processor may only be competitive for ewes during those periods of the year when political factors in Mexico impede live ewe buying.

Key words: cull ewe, sausage, kabobs, value-added, sheep.

Introduction

Due to the higher prices received for cull ewes in recent years from their export to Mexico, the sheep industry has not viewed cull ewe marketing as a problem. However, a careful review of this market shows that the Mexican purchase of cull ewes is both sporadic or seasonal and highly variable in market price (USDA, 1997). Further, those northern and western states remote from the Mexican border in Texas are at a significant market price disadvantage.

Mutton is a by-product of the sheep industry that suffers from marketing neglect due to low volume and consumer prejudice. Traditional American consumers view mutton as a tough piece of meat with an objectionable flavor, yet most have not even tasted mutton. This is in stark contrast to some cultures where mutton is desired because it is utilized in complex traditional preparations with spices and condiments that compliment the stronger mutton flavor. Niche or ethnic markets such as Hispanic, Asian and Middle Eastern populations are becoming increasingly important in certain areas of the United States and these populations traditionally consume mutton. The sheep industry may be better served if research and market development concentrated on finding specialty and niche markets and products where mutton's unique characteristics are acceptable.

Developing innovative products such as unique sausages and restructured items have been proposed as a way of adding value. Some previous work showed promise in developing mutton products and studied restructured roasts (Prasad et al., 1987; Hand et al., 1993) and sausage (Anderson and Gillett, 1974; Bartholomew and Osuala, 1986; Bond et al., 1990; Wu et al., 1991).

After some exploratory discussions between University of Nevada – Reno (Est. 6004) personnel and a cooperating local supermarket chain, it was decided that sausage products and cubes for kabobs had the greatest market potential. The supermarket

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Figure 1. Point-of-sale advertisement used at each supermarket meat case. The placard was 22.86 cm × 30.48 cm on a blue background.

meat section management was not interested in a restructured product because of the large number of poultry and pork items that are very price competitive.

The supermarket management strongly suggested that a brand theme be established. The supermarket's advertising agency felt they could promote the theme of the early Basque sheepherders who had emigrated from the Pyrenees Mountains of France and Spain and were associated with a rural lifestyle and a positive image. We worked with the Basque Studies program at the University of Nevada – Reno to verify the facts and design a point-of-sale placard (Figure 1) for the in-store promotion. It was decided to utilize this positive image that the Basque people had in the intermountain region of the U.S. to promote a product from a way of life associated with their sheepherding activities. This study proposed to develop and market a branded product made from mutton and to utilize the whole ewe carcass.

Materials and Methods

The boneless mutton, lean trim and cubes for kabobs, from the rib, loin and leg, produced by processing 60 carcasses from 4- to 6-year-old ewes (Glimp et al., 1998) were used in this study. Five carcasses per week were processed and merchandised over a 3-month period. After preliminary discussions between university personnel and supermarket management, all mutton products were developed and tasted by meat lab and supermarket personnel. From this process of trial and error, four products passed the informal taste tests. Processes were documented and labels (Figure 2) were developed for USDA Inspection approval. Although the preferred spelling is "kabob" (NLSMB, 1995), the label application (Figure 2) used the alternative spelling ("kebob") because the supermarket computer system, pricing machine and promotional material had always used the kebob spelling. It is far better to build on a promotional program and name recognition that the supermarket already has in place.

Dinner Sausage

The dinner sausage is a fresh product made from boneless mutton and mutton lean trim. The mutton was ground once through a 0.48-cm plate. The ingredients (grated parmesan cheese, garlic salt, oregano, basil, onion powder, mustard seed) were added to the first grind and mixed. This batch was reground through a 0.32-cm plate and stuffed into a hog casing.

Smoked Sausage

The smoked sausage was a cured product made from boneless mutton and mutton lean trim which was first ground once through a 0.95-cm plate. The seasonings (salt, corn syrup solids, dextrose, spice, flavorings, monosodium glutamate, sodium erothorbate) were added after the first grind and mixed. The cure (salt, sodium nitrite) was added separately and mixed a second time. This batch was reground through a 0.48-cm plate and stuffed into a hog casing. The product was placed on a smokestick and seasoned overnight at 0.5 to 4.5 °C. The sausage was cooked to 57 °C along with natural smoke and then cold-water showered.

Chorizo

Although traditional chorizos are made from pork, mutton was substituted to develop a sheep chorizo which was a slightly dried mutton product with a reddish color from the chili pepper. The meat was ground once through a 0.95-cm plate. The ingredients (vinegar, water, salt, California chili pepper, garlic powder, black pepper) were added, mixed with the meat and stuffed into a hog casing. The product was placed on a smoke stick and air dried for 48 hours at 0.5 to 4.5 °C.

Shish Kabob

The shish kabob was a home meal replacement (HMR) type of product. The rib, loin and leg muscles were all needled with a hand-operated Jaccard unit before they were cut into cubes for kabobs. For a list of the major muscles used, please refer to the companion paper (Glimp et al., 1998) which appears on pages 180 to 184 of this journal. The cubes for kabobs were vacuum tumbled for 10 to 30 minutes in a solution of red wine, olive oil, garlic powder, onion powder, black pepper and salt. The maximum weight gain from the marinade solution was 10%. If the maximum weight gain was exceeded, the product was placed in a colander and drained until the weight gain came down to the 10% limit. The marinated cubes were placed on a bamboo stick with alternating pieces of green and red bell peppers, onion and mushroom.

Retail Packaging

The sausage products and shish kabob were packaged in a retail-ready overwrapped tray. Individual packages were weighed and the pricing scale produced the store label with the chain logo, the Universal Product Code retail cut name (NLSMB, 1995), weight, price per pound, total price and pull date. The price per pound produced approximately a 25% gross margin for the supermarket. The supermarket management was willing to accept less than their target of 30% since the only requirement for the meat department personnel was to place the packages in the retail meat display case. Records kept by supermarket personnel indicated a discard

Figure 2. Color USDA-approved product labels were applied to each retail ready tray by the processor when product was being packaged. Individual labels measured 6.35 cm × 8.89 cm.

rate of approximately 1.5%. It was almost zero for the smoked sausage and chorizo with shish kabob accounting for most of the product loss. The safe-handling label was applied by hand. The product label (Figure 2) was also applied at this time and the product was boxed for store delivery. The boxes were picked up by a refrigerated truck from the supermarket delivery fleet and distributed to the stores. All 17 stores in the organization ordered the processed mutton products throughout the trial. Temperature was monitored so the product was kept as close to the 0 to 2 °C range as possible.

The data were analyzed as a completely randomized design with body condition level (high condition [HC], medium condition [MC], low condition [LC]; please refer to the companion paper [Glimp et al., 1998] which appears on pages 180 to 184 of this journal) as the main effects using GLM procedures of SAS (1988). Using least squares means procedure (SAS, 1988), the least significant difference procedure was used for means separation if a significant F-test was detected (Steele and Torrie, 1980).

Results and Discussion

Development and Distribution to a Small Local Supermarket Chain

A joint decision was made by the production and marketing personnel to request labels listing sheep rather than mutton. Because of the Basque theme, "sheep" enjoyed a much more positive image as compared to using "mutton" in the ingredients list on the label (Figure 2).

After receiving approval for labels and product procedures, a preliminary production run was made to see if the mutton products would actually be selected by shoppers from the supermarket retail case. Chorizos, smoked sausages and shish kabobs all received positive consumer responses as indicated by purchasing the products and continued sales. However, dinner sausage received limited shopper response probably because it lacked eye appeal due to color deterioration. Therefore, dinner sausage was immediately dropped from the product line. Because of prior joint research projects, university personnel knew all 17 meat market managers on a first name basis. Product sales, which was our proxy for consumer response, was monitored on a biweekly basis.

All the major muscles of the rib, loin and leg were processed into cubes for kabobs. The remaining boneless mutton and lean trim were processed into sausage with approximately equal amounts of chorizo and smoked sausage being produced.

The boneless mutton and lean trim from the HC ewe carcasses were marginally acceptable sausage products, at approximately 20% fat as determined by the product development group made up of university and supermarket personnel. The MC ewes produced mutton and lean trim approximately 15% fat from raw sausage materials which made the best sausage from the feedback of meat department managers. The LC ewes produced raw materials that were less than 10% fat which was too lean to produce an acceptable sausage product. However, by blending approximately equal amounts of boneless mutton and lean trim from LC and HC ewe carcasses, a very acceptable sausage product of approximately 15% fat could be made. Consumer feedback through the supermarket meat managers indicated that mutton sausages needed to be approximately 15% fat which would agree with Bond et al. (1990) and Hand et al. (1993). Palatability suffered when fat was below or above this benchmark. Shoppers also had a very negative perception of the appearance as indicated by lack of purchases when the fat level reached 20% and especially if it exceeded this level.

Table 1. Least square means and standard errors (SE) for ewe value calculated from processing a whole ewe carcass into boneless rib, loin and leg for cubes for kabobs and the remaining lean trim to sheep sausage sold directly to a small supermarket chain.

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Rib, loin and leg/ewe, kg[a]	3.89[j]	0.15	4.15[j,k]	0.26	4.73[k]	0.20
Cubes for kabobs value/ewe, $[b]	32.29[j]	1.27	34.59[j,k]	2.16	39.28[k]	1.65
Lean trim/ewe, kg[c]	11.78[j]	0.43	12.64[j,k]	0.50	13.50[k]	0.45
Sausage value/ewe, $[d]	59.21[j]	2.18	63.51[j,k]	2.52	67.86[k]	2.25
Product income/ewe, $[e]	91.50[j]	2.19	98.10[j,k]	4.29	107.15[k]	3.37
Processing charges/ewe, $[f]	34.80[j]	0.50	36.16[j,k]	0.84	37.87[k]	0.68
Live market value/ewe, $[g]	56.70[j]	1.70	61.94[j,k]	3.45	69.27[k]	2.69
Live ewe market value/0.454 kg, $[h]	0.396	0.01	0.405	0.02	0.420	0.01

[a] Rib, loin and leg major muscles were removed, defatted and silver side removed and processed into cubes for kabobs.

[b] Cubes for kabobs value/ewe = rib, loin and leg, kg × $8.33.

[c] Carcass parts remaining were boned and trimmed to produce boneless mutton circa 15 to 20% chemical fat if the carcass carried sufficient fat.

[d] Sausage value/ewe = lean trim/ewe, kg × $5.04.

[e] Product income/ewe = cubes for kabobs value/ewe + sausage value/ewe.

[f] Processing charges = $8.00 (for slaughter costs) + $1.20 × carcass weight, kg + $8.00 (for processor gross profit margin).

[g] Live market values/ewe = product income/ewe − processing charges/ewe.

[h] Live ewe market value/0.454 kg = live market value/ewe ÷ live weight, kg/0.454 (see Table 1 of the companion paper [Glimp et al., 1998] on page 181).

[j,k] Row means that do not have a common superscript differ ($P < 0.05$).

The values in Table 1 were the actual returns experienced by the processor. Assumptions were made for slaughter and processing costs which are listed in the table footnotes. The LC ewes were different (P < 0.05) from the HC ewes in all their traits except the live ewe market value/unit weight. The MC group was not different (P < 0.05) from either the LC or HC groups. Although the value/unit weight increased slightly from LC to HC, there was no difference (P < 0.05) among the LC, MC and HC groups in live ewe market value/unit weight. This was probably due to dressing percent (see please refer to Table 1 of the companion paper (Glimp et al., 1998) which appears on page 181 of this journal) increasing with increasing fatness.

Table 2 represents what would happen if the supermarket chain would buy only sausage products and no value-added items such as shish kabobs. The relationships between the groups remain the same as Table 1. However, the live ewe market value/unit weight decreases approximately 17% when compared to Table 1. This is due to the higher price of the value-added product represented by shish kabobs in Table 1.

Hypothetical Distribution Through a Wholesaler

If the sheep processor is unable to sell a retail ready product to a local supermarket chain, it may be possible to distribute the product through a wholesaler. Obviously, the wholesaler will charge a fee for his services. This is represented in Tables 3 and 4 by lowering the price of raw materials by $0.20 per 0.454 kg. This method of distribution would lower live ewe market value/unit weight by approximately 12% (Table 1 vs. Table 3).

As volume increases, it may be more difficult to process and sell all the rib, loin and leg as shish kabob. This would lower live ewe market value/unit weight by approximately 19% (Table 4 vs. Table 3). Live ewe market value/unit weight would be decreased almost 30% if only sausage products could be sold through a wholesaler (Table 4 vs. Table 1). Although not estimated, it is likely that slaughter and processing costs would be reduced significantly in a larger scale operation.

Table 2. Least square means and standard errors (SE) for ewe value calculated from processing a whole ewe carcass to sheep sausage sold directly to a small supermarket chain.

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Boneless mutton/ewe, kg[a]	15.67[f]	0.42	16.80[f,g]	0.70	18.23[g]	0.57
Product value/ewe, $[b]	78.74[f]	2.09	84.43[f,g]	3.54	91.62[g]	2.86
Processing charges/ewe, $[c]	31.67[f]	0.42	32.80[f,g]	0.70	34.23[g]	0.57
Live market value/ewe, $[d]	47.07[f]	1.68	51.63[f,g]	2.84	57.39[g]	2.29
Live ewe market value/0.454 kg, $[e]	0.327	0.01	0.338	0.01	0.348	0.01

[a] Carcass was boned and trimmed to produce boneless mutton circa 15 to 20% chemical fat if the carcass carried sufficient fat.

[b] Product value/ewe = total boneless mutton, kg × $5.04.

[c] Processing charges = $8.00 (for slaughter costs) + $1.00 × carcass weight, kg + $8.00 (for processor gross profit margin).

[d] Live market values/ewe = product value/ewe − processing charges/ewe.

[e] Live ewe market value/0.454 kg = live market value/ewe ÷ live weight, kg/0.454 (see Table 1 of the companion paper [Glimp et al., 1998] on page 181).

[f,g] Row means that do not have a common superscript differ (P < 0.05).

Table 3. Least square means and standard errors (SE) for ewe value recalculated from processing a whole ewe carcass to boneless rib, loin and leg cubes for kabobs and the remaining lean trim to sheep sausage sold to a wholesale distribution system.

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Rib, loin and leg/ewe, kg[a]	3.89[j]	0.15	4.16[j,k]	0.26	4.73[k]	0.20
Cubes for kabobs value/ewe, $[b]	30.58[j]	1.20	32.75[j,k]	2.04	37.20[k]	1.56
Lean trim/ewe, kg[c]	11.78[j]	0.43	12.64[j,k]	0.50	13.50[k]	0.45
Sausage value, $[d]	54.02[j]	1.99	57.94[j,k]	2.30	61.91[k]	2.05
Product income/ewe, $[e]	84.59[j]	2.01	90.69[j,k]	3.98	99.11[k]	3.12
Processing charges/ewe, $[f]	34.80[j]	0.50	36.16[j,k]	0.84	37.87[k]	0.68
Live market value/ewe, $[g]	49.80[j]	1.53	54.54[j,k]	3.14	61.24[k]	2.44
Live ewe market value/0.454 kg, $[h]	0.347	0.01	0.357	0.02	0.371	0.01

Rib, loin and leg major muscles were removed, defatted and silver side removed and processed into cubes for kabobs.

[b] Cubes for kabobs value/ewe = rib, loin and leg, kg × $7.89.

[c] Carcass parts remaining were boned and trimmed to produce boneless mutton circa 15 to 20% chemical fat if the carcass carried sufficient fat.

[d] Sausage value/ewe = lean trim/ewe, kg × $4.60.

[e] Product income/ewe = cubes for kabobs value/ewe + sausage value/ewe.

[f] Processing charges = $8.00 (for slaughter costs) + $1.20 × carcass weight, kg + $8.00 (for processor gross profit margin).

[g] Live market values/ewe = product income/ewe − processing charges/ewe.

[h] Live ewe market value/0.454 kg = live market value/ewe ÷ live weight, kg/0.454 (see Table 1 of the companion paper [Glimp et al., 1998] on page 181).

[j,k] Row means that do not have a common superscript differ (P < 0.05).

Implications

It is acknowledged that: 1) traditional American consumers may not consume mutton; and 2) for much of the sheep-producing area of the United States the sale of cull ewes to Mexico is an attractive market most of the year. However, the expanding Hispanic and other ethnic markets in the U.S. may provide an attractive market for sausage and other products from mutton. Specialty products such as the shish kabob described in this study can significantly add value to mutton when the processor is producing for local markets, but may have limited application in broader distribution situations. The wholesale and retail prices established in this study were acceptable to both the retailer and the consumer; however, these prices may be higher, or lower, than those that would be appropriate for other markets. The low end of the price range (Table 4) justified by manufactured mutton products is slightly higher than ewe prices (circa $0.25/0.454 kg) when sheep are prevented from entering Mexico. The high end coincides with live ewe prices (circa $0.40/0.454 kg) when Mexico in actively bidding in the U.S. market (USDA, 1997). The ideal ewe is in medium condition so as to produce raw materials of approximately 15% fat. Boneless mutton and lean trim from low and high condition ewes can also be blended to produce products with the same percent fat. It is very important to produce raw materials which are approximately 15% fat as palatability and appearance suffer if the processor strays very much from this benchmark. Close coordination between the processor and retail segment is absolutely necessary if the introduction of branded products is to be successful.

Table 4. Least square means and standard errors (SE) for ewe value recalculated from processing a whole ewe carcass to sheep sausage sold to a wholesale distribution system.

	Body condition group					
	Low		Medium		High	
Item	Mean	SE	Mean	SE	Mean	SE
Boneless mutton, kg[a]	15.67[f]	0.42	16.80[f,g]	0.70	18.23[g]	0.57
Product income/ewe, $[b]	71.83[f]	1.91	77.02[f,g]	3.23	83.58[g]	2.61
Processing charges/ewe, $[c]	31.67[f]	0.42	32.80[f,g]	0.70	34.23[g]	0.57
Live ewe market value, $[d]	40.17[f]	1.49	44.23[f,g]	2.52	49.36[g]	2.04
Live ewe market value/0.454 kg, $[e]	0.279	0.01	0.289	0.01	0.299	0.01

[a] Carcass was boned and trimmed to produce boneless mutton circa 15 to 20% chemical fat if the carcass carried sufficient fat.

[b] Product income/ewe = total boneless mutton, kg × $4.60.

[c] Processing charges = $8.00 (for slaughter costs) + $1.00 × carcass weight, kg + $8.00 (for processor gross profit margin).

[d] Live market values/ewe = product income/ewe − processing charges/ewe.

[e] Live ewe market value/0.454 kg = live market value/ewe ÷ live weight, kg/0.454 (see Table 1 of the companion paper [Glimp et al., 1998] on page 181).

[f,g] Row means that do not have a common superscript differ ($P < 0.05$).

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The Proportion of Lambs Born at Night is Not Changed by Lighting

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Summary

During April and the first week of May in 1995 and 1996, lambing times on 258 mature white-faced ewes from two different flocks were recorded to determine if night lighting influences time of parturition. One flock where 165 parturition times were recorded lambed in a well lighted barn. Another flock where 93 parturition times were recorded lambed in unlighted facilities and were checked at night with a flashlight. Both flocks were fed alfalfa hay and 1.5 pounds of grain once a day between 0700 and 0800 hours. Number of ewes lambing in each of 6 4-hour periods in each flock yielded a Chi-square probability of $P < 0.84$ showing that lambing in lighted or unlighted facilities did not change parturition times. However, large deviations from a random distribution ($P < 0.001$) for time of parturition were present when lighted and unlighted treatments were pooled. More parturitions occurred from 0800 to 1200 hours and fewer occurred from 2000 to 0000 hours than during other 4-hour periods throughout the day. It is clear that neither lighting nor feeding time can be used to determine birth time of all lambs and that night-time observation during lambing is still required. Nevertheless, our findings confirm other studies showing that sheep producers can spend less time lambing at night if a morning feeding time is included as a part of the management system.

Key words: sheep, parturition, lighting, feeding, management.

Introduction

One of the survival goals for the sheep industry is to improve efficiency and decrease costs of production. Steps to accomplish this goal include increasing lambing percentage and decreasing labor costs. Under some management systems more lambs could be saved and labor costs reduced if lambs were born during daylight hours when the temperature is often higher and observation of the flock is easier.

Studies have shown that pregnant beef cows fed in the late evening had more calves born during daylight hours than pregnant beef cows fed in the morning (Yarney et al., 1979; Lowman et al., 1981). Nevertheless, Jilek et al. (1985) and Hudgens et al. (1986) found little effect of feeding time on parturition in ewes. In contrast, Gonyou and Cobb (1986) showed that 64.9% of the lambings occurred between 4 hours prior to and 8 hours after feeding. They concluded that a large proportion of daytime births can be achieved by feeding in the morning and that late morning feeding is best to reduce late night parturitions. Fahmy et al. (1997) reported lambing time in prolific and non-prolific sheep fed twice a day at 1000 and 1400 hours. About 57% of Romanov, 47% of Finnsheep and 27% of Suffolk ewes lambed between 1600 and 0000 hours and 29, 47 and 60%, respectively, lambed between 0800 and 1600 hours. The lowest percentage of parturitions in the three breeds (14.2, 5.3, 13.3%, respectively) occurred between 0000 and 0800 hours. Parker (1995) believes that daytime parturitions are increased when a 7.5 watt bulb is the only night light in the lambing barn. He found that feeding at 1200 hours and using a flashlight at night when additional light is needed resulted in 66% of the ewes lambing between 0600 and 1800 hours. However, no control flock existed where the lights were left on at night. Our present study is the first to compare distribution of parturitions when ewes are housed in a well-lighted building compared to a dark night time environment.

Materials and Methods

During April and the first week of May in 1995 and 1996, lambing times on 258 mature white-faced ewes from two different flocks were recorded. One flock lambed in a well lighted barn at the University of Wyoming Livestock Center (Laramie, WY) where lights were left on all night

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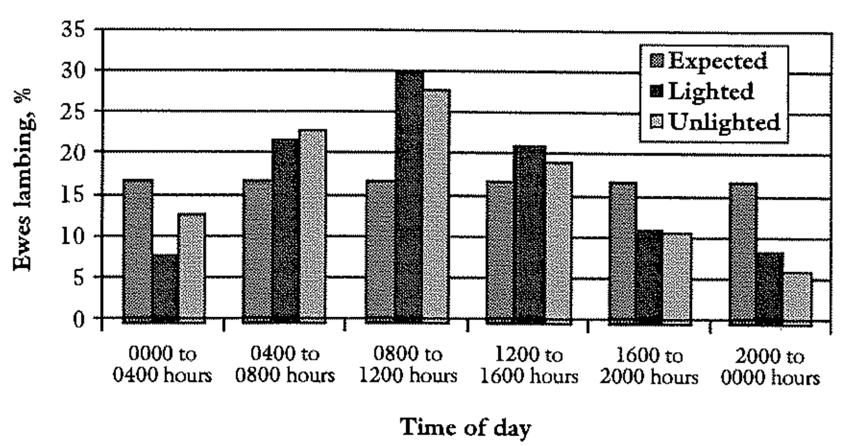
with an attendant present. Another flock lambed at a farm in an open shed where no lighting existed. Both flocks of ewes were fed alfalfa hay and 1.5 pounds of grain once a day between 0700 and 0800 hours but the feed bunks were open and some feed remained in the bunks throughout the day. At night ewes in the unlighted farm flock were checked with a flashlight every 2 hours by a different attendant than the one in the lighted barn. Efforts were made not to disturb the ewes when they were checked at night or when ewes and newly born lambs were removed from the flock and placed in individual pens in an adjacent barn.

Time-of-lambing data were analyzed by location and by deviations from a random distribution during 4-hour periods throughout the day starting at 0000 hours. All data were analyzed employing the CATMOD procedure of SAS (1985). Comparison of time-of-lambing data in the lighted and unlighted facilities is confounded with location, ewe genetics and other management considerations. It is recognized that this confounding may have masked the true treatment effects.

Results and Discussion

Times of parturition for ewes held at night with the lights on and for ewes lambing in unlighted facilities are found in Figure 1. Number of ewes lambing in each of the 6 4-hour periods beginning at 0000 hours are shown. Distribution of number of lambs born in each 4-hour period was not influenced by lighting. The Chi-square probability for lighting was $P < 0.84$. However, large deviations from a random distribution ($P < 0.001$) for time of parturition were present when the data for light and dark treatments were pooled. The interval from 0800 to 1200 hours contributed the largest deviation from a random distribution and the time from 2000 to 0000 hours the second largest. Seventy-five out of the 258 ewes (29%) lambed from 0800 to 1200 hours while only 20 ewes (7.75%) lambed from 2000 to 0000 hours. Parker (1995) believes that feeding at noon and then lambing in the dark during nighttime hours is the best way to encourage daytime lambing. With this practice only 16% of his ewes lambed between 2200 and 0600 hours. In our study 72% of the 258 ewes lambed between 0400 and 1600 hours with 11, 8 and 9% lambing in the 1600 to 2000 hours, 2000 to 0000 hours and 0000 to 0400 hours time periods, respectively. Our findings support research of others who report a large proportion of daytime births and few late night births when ewes are fed in the morning (Gonyou and Cobb, 1986; Lindahl, 1964; Holmes, 1976). Studies of Hudgens et al. (1986) and Jilek et al. (1985) failed to detect an effect of time of feeding on time of lambing but both groups reported fewer ewes lambed at night. Hudgens et al. (1986) found that only 25% of the ewes in their study lambed between 1900 and 0300 hours, while Jilek et al. (1985) reported 42% of the ewes lambed from 1800 to 0600 hours. Fahmy et al. (1997) fed twice a day at 1000 and 1400 hours and reported only 14.2, 5.3 and 13.3% of the parturitions in Romanov, Finnsheep and Suffolk ewes, respectively, occurred between 0000 and 0800 hours. George (1969) correlated lambing time with breed. He found that significantly more Merino ewes lambed at night while more Dorset Horned ewes lambed during the day. The study of Arnold and Morgan (1975) also is at variance with others reporting that fewer ewes lamb at night. Gonyou and Cobb (1986) hypothesized this may be related to the ewes being on pasture during lambing while in all other trials the ewes lambed in pens or in barns.

Figure 1. Percentage of ewes lambing in lighted and unlighted areas by time of day.



Feeding ewes in the morning or at noon to produce more daytime lambings is in contrast to results with cattle showing that daytime parturitions can be increased by feeding in the evening (Yarney et al., 1979; Lowman et al., 1981; Clark et al., 1983; Muller and Moon, 1983). Both cattle and sheep are ruminants but gestation times are different and it does not necessarily follow that the time of feeding should influence the time of parturition in both species in the same manner. Support for this statement can be found in the work of Gordon (1996) who observed that there is a difference between cows and ewes in permeability of the placenta to synthetic corticosteroids that induce parturition. Ewes are more resistant to corticosteroids than cows and differences such as this may help to explain why cows need to be fed in the evening while ewes need to be fed in the morning or at noon to produce more daytime parturitions. It is clear from all studies on both sheep and cattle that feeding time will not determine birth time of all young and that nighttime observation is still required. Nevertheless, sheep producers should benefit by spending less time at night when morning or noon feeding time is included as a part of the management system.

Conclusions

No differences in time of parturition were observed when ewes were held in artificial light or in darkness during the night. However, a high percentage of the parturitions occurred during the day. This may be related to the morning feeding schedule and to daytime movement of the ewes. More lambs born during the day should benefit overall management.

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Political Economy of United States Sheep Industry Political Action Committees

Terry D. Van Doren[1], Thomas G. Field[1,2] and Dana L. Hoag[3]

Summary

This study evaluated the political activity of sheep and wool industry Political Action Committees (PACs). The study addressed three major questions: 1) What factors affect sheep industry PAC contributions?; 2) What are sheep industry PACs attempting to gain with their PAC contributions?; and 3) Are the PAC giving strategies of the sheep industry similar to other agricultural PACs? Analysis revealed that sheep PACs follow a fairly narrow contribution strategy, targeting only two legislative attributes, agricultural committee membership and percent of state in farmland. This narrow, political behavior may be a result of limited funding and specific industry goals. Furthermore, sheep and wool PACs follow an access-seeking strategy, hoping to assure an "open door" to legislators and their staff. Finally, the comparison of sheep industry PAC strategies with other agriculture and animal industry PACs found that inconsistent collaboration exists between sheep industry and other agricultural PACs. As the number of people involved in sheep and wool production continues to dwindle, closer coordination between agricultural PACs may be warranted.

Key words: Political Action Committees (PACs), sheep industry.

Introduction

From 1992 through 1995, 16,000 U.S. farms eliminated their sheep enterprise (USDA, 1996). As the number of people involved in the sheep industry decreases, we would expect sheep producers' political influence to decrease.

In fact, the sheep industry has lost substantial political battles in recent years over issues such as the Wool Act. Currently, issues vital to the sheep industry, such as grazing fees, private property rights, animal damage control, Endangered Species Act reform, tax reform, regulatory reform and various environmental issues, are under consideration. Political losses in these areas could be damaging to the sheep industry. Carande et al. (1995) have already quantified the negative impact of wool incentive losses and grazing fee increases on sheep producer viability. In an era of political uncertainty, it is vital that sheep producers attempt to impact the political environment and the economic realities of the public policy process.

One way that industries can attempt to maintain political influence is through Political Action Committees (PACs). PACs are organizations that solicit money from association members and then attempt to affect the political process by, among other things, distributing monies to political candidates. In fact, the American Sheep Industry Association (ASI) maintains RAMS PAC which raises and distributes approximately $30,000 per two-year political cycle. Contribution decisions are made by the RAMS PAC committee which consists of executive committee officers and the legislative council chair. ASI lobbyists serve as ex-officio members of this decision making body.

The objective of this study was to evaluate the political impact of sheep industry PAC expenditures. The analysis addresses the following questions:

1. Which factors affect sheep industry PAC contribution strategies: political party, legislator ideology, constituent concerns, key committee membership, legislator seniority levels or election margins?
2. What are sheep industry PACs attempting to gain: ideological election outcomes or access to legislators and staff?
3. Are the PAC giving strategies of the sheep industry similar to other agricultural PACs?

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Materials and Methods

Phase I: Which Variables Affect PAC Contributions

PAC contribution data was supplied by the Center for Responsive Politics in Washington, DC. The data include all nonindependent expenditures to senators serving during the 103rd Congress (1993 to 1994). PAC contributions from 1989 through 1994 (6 years) are included in the analysis.

Using PAC contribution data as a dependent variable presents statistical challenges. PAC contributions have many zero observations which biases ordinary least squares estimates. Past research (Tobin, 1958; Grier and Munger 1986, 1991, 1993) suggests TOBIT as the appropriate statistical procedure. The TOBIT procedure estimates a nonlinear maximum likelihood and then generates linear β coefficients.

The independent variables for all three phases of this study included: party, ideology, electoral security, seniority, state's dependence on agriculture and key committee membership. Legislators' *party* affiliations may indicate their ability to access congressional leadership and serve as committee chairs. A similar variable, *ideology*, denotes a legislator's conservatism or liberalism. Sheep interest PACs might logically target those senators who were ideologically predisposed toward sheep industry positions.

Electoral security is a measure of a legislator's need for political funds. If a legislator is expecting a close election race and the demand for political money is higher, will sheep industry PACs supply more money? A legislator's *seniority* is a good indicator of leadership position, collegial respect and parliamentary prowess. These assets might attract PAC investments.

A *state's dependence on agriculture* (STFarmP) is used as a measure of constituent concerns. The literature has pointed to the interests of a legislator's constituency as a determinant of campaign contributions received (Kau et al., 1982; Denzau and Munger, 1986; Grier and Munger, 1991; G.C. Wright, 1989). PACs may simply use contributions to enhance the visibility of a constituency group represented in a legislator's district. If a legislator's constituency is sympathetic or indifferent toward agricultural issues, the legislator will be more likely to vote favorably on agricultural legislation.

Jurisdictional committees play a significant role as gatekeepers and agenda setters. Committees essentially have "effective veto power" over issues within their jurisdiction (Denzau and Mackay, 1983). However, certain committees have more value to sheep interests than others. *Key committees* of the agricultural industry were identified through informal interviews with five lobbyists representing both production and agribusiness interests. A committee was considered to be a key committee if it was identified by three of the five interviewed lobbyists. This interview process yielded a list of six key committees:

1. Committee on Agriculture, Nutrition and Forestry (AGCOM);
2. Appropriations Subcommittee on Agriculture, Rural Development and Related Agencies (AGAPPR);
3. Committee on Finance (FINANCE);
4. Committee on Environment and Public Works (ENVPW);
5. Committee on Commerce, Science and Transportation (COMMERCE); and
6. Committee on Labor and Human Resources (LABOR).

All factors discussed above were integrated into the model and regression coefficients were generated for the equation shown in Figure 1. A more complete specification of this study's independent variables can be found in Table 1.

Insignificant variables were deleted from the equation using the following decision-making protocols. First, variables were evaluated using asymptotic t-statistics. Johnston (1984) recommended that researchers balance model efficiency and bias by using a conditional omitted variable estimation technique that drops all variables with a t-statistic of less than one. This method was employed for two iterations. Next, all variables with p-values greater than 0.15 were deleted. This method was also utilized for two iterations. After the four statistical iterations, Chi-square tests confirmed the eliminated variables were not significantly different than zero at the 0.05 level.

Phase I Hypotheses

Hypothesis I-1:
Sheep industry PACs will contribute more to Republicans *(Expected β coefficient sign on PARTY: +).*

Hypothesis I-2:
Sheep producer PACs will contribute more to conservative senators *(Expected sign on IDEOLOGY: +).*

Hypothesis I-3:
Sheep producer PACs will contribute more to senators from states that are highly dependent on agriculture *(Expected sign on STFarmP: +).*

Hypothesis I-4:
Sheep industry PACs will contribute more to senators on key committees such as the agriculture, nutrition and forestry committee; the agriculture appropriations subcommittee; the finance committee; the environment and public works committee; the commerce, science and transportation committee; and the labor and human resources committee *(Expected sign on committee variables: +).*

Hypothesis I-5:
Sheep industry PACs will be likely to target senators who face a tight re-election race *(Expected sign on MARGIN: -).*

Figure 1. PAC contribution effects model.

$$PAC = \alpha + \beta_1 PARTY + \beta_2 IDEOLOGY + \beta_3 IDEOLOGY^2 + \beta_4 SENIORITY + \beta_5 SENIORITY^2 + \beta_6 STFarmP + \beta_7 AGCOM + \beta_8 SENAGC + \beta_9 AGAPPROP + \beta_{10} FINANCE + \beta_{11} ENVPW + \beta_{12} COMMERCE + \beta_{13} LABOR + \beta_{14} MARGIN$$

Hypothesis I-6:

Sheep producer PACs will give more support to "seasoned" senators *(Expected sign on SENIORITY: +).*

Phase II: What are Sheep Industry PACs Attempting to Achieve?

Political analysts contend that PACs follow one of two strategies: an ideological election outcomes strategy, or an access strategy. An ideological election outcomes strategy involves attempting to affect election out-comes by contributing to candidates who are ideologically predisposed to the PAC's policy positions. Once elected, the legislator will be likely to vote in the PAC's favor (Conway, 1991; Eismer and Pollock, 1986; Kau et al., 1982, Schlozman and Tierney, 1986; Grenzke, 1989; Gardner, 1995).

Conversely, an access-seeking PAC attempts to purchase an open door to legislators and their staff. This open door may be used by lobbyists to highlight interest group concerns. Many have asserted gaining access is the primary motive of PACs (Truman, 1951; Eismer and Pollock, 1986; Langbein, 1986; Denzau and Munger, 1986; Langbein and Lotwis, 1990; Hall and Wayman, 1990; Grier and Munger, 1991; Langbein, 1993).

Phase II attempted to empirically identify the PAC contribution strategy employed by sheep industry PACs. β Coefficients from Phase I with a p-value of 0.10 or better were classified as a targeted attribute. These targeted attributes were then utilized in a cate-

Table 1. Independent variable descriptions and summary statistics.

Variable	Description	Source
Party	Political party (Democrat = 0; Republican = 1).	Vital Statistics on Congress, 1993-94
Ideology	The weighted average of each Senator's 1993 and 1994 Conservative Coalition Support Indexes. The 1993 index is a % of 41 recorded votes and the 1994 index is a % of 32 recorded votes where the Senator voted in agreement with the Conservative Coalition's position. The weighted average was figured using the following formula: {(1993 index × 41) + (1994 index × 32)} ÷ (41 + 32).	1993-94 Congressional Quarterly Almanacs
Ideology²	Quadratic term: the square of the above weighted average of each Senator's Conservative Coalition Support Indexes.	1993-94 Congressional Quarterly Almanacs
Seniority	Years of service in the U.S. Senate.	Vital Statistics on Congress, 1993-94
Seniority²	Quadratic term: the square of the seniority variable.	Vital Statistics on Congress, 1993-94
State Farm Percent	Percent of state's land area in farmland.	National Agricultural Statistics Service
Agriculture Committee	Membership in the Committee on Agriculture, Nutrition and Forestry = 1; nonmember = 0.	1993-94 Congressional Directory: 103rd Congress
Agriculture Appropriations Subcommittee	Membership in the Appropriations subcommittee on Agriculture, Rural Development and Related Agencies = 1; nonmember = 0.	1993-94 Congressional Directory: 103rd Congress
Finance Committee	Membership in the Committee on Finance = 1; nonmember = 0.	1993-94 Congressional Directory: 103rd Congress
Environment and Public Works Committee	Membership in the Committee on Environment and Public Works = 1; nonmember = 0.	1993-94 Congressional Directory: 103rd Congress
Commerce Committee	Membership in the Committee on Commerce, Science and Transportation = 1; nonmember = 0.	1993-94 Congressional Directory: 103rd Congress
Labor and Human Resources Committee	Membership in the Committee on Labor and Human Resources = 1; nonmember = 0.	1993-94 Congressional Directory: 103rd Congress
Electoral Margin	Margin in last election. Calculated with this formula: Senator's % of vote in election race (1989 through 1994) - closest challenger's vote %.	Almanac of American Politics, 1996
Seniority by Agriculture Committee Interaction	Interaction term involving the seniority and the agriculture committee variables.	–

gorization model developed by Evans (1988) who classified PACs as either pragmatic or ideological. Pragmatic PACs are characterized as those who attempt to gain access to legislators; ideological PACs are those attempting to change the composition of Congress to a more ideologically compatible conformation. Evans (1988) noted: "An ideological strategy arises from the assumption that members' behavior cannot be influenced by PAC contributions; to change the decisions that Congress makes the PAC must change the composition."

The indicators of ideological behavior included: contributions to ideologically compatible members, and contributions to members of a preferred political party (Handler and Mulkern, 1982; Gopoian, 1984; J. Wright, 1985; Evans, 1988).

Evans (1988) asserted that a pragmatic PAC strategy involves: contributions to key committee members (Sabato, 1984; Brown, 1983; Gopoian, 1984; J. Wright, 1985; Sabato, 1984; Latus, 1984); contributions to legislators from districts where constituents are concerned with the PAC's issues (Sabato, 1984; Gopoian, 1984); and contributions to legislators in safe seats (Welch, 1979; Brown, 1983; J. Wright, 1985).

Phase II Hypotheses

Agricultural PACs seeking to affect election outcomes will:

Hypothesis II-1:
Invest in ideologically agreeable incumbents.

Hypothesis II-2:
Contribute mainly to either Republican or Democratic candidates.

Hypothesis II-3:
Contribute disproportionately to incumbents that are electorally vulnerable.

If all three hypotheses were found to be true for a PAC subsector then that sector was coded as following an election outcomes strategy.

Agricultural PACs seeking to gain access to senators and their staff will:

Hypothesis II-4:
Contribute mainly to senators from agriculturally dependent states.

Hypothesis II-5:
Disproportionately invest in senators on a key committee.

Agricultural subsectors were required to fulfill both of the final hypotheses to be considered an access-seeking group.

Phase III: Are the Sheep Industry PAC Giving Strategies Similar to Other Agricultural PACs?

Many researchers have noted that interest groups often create both formal and informal alliances to address legislative concerns (Bosso, 1988; Gais et al., 1984; Light, 1985; Loomis, 1986; McFarland, 1992; Ornstein and Elder, 1978; Salisbury et al., 1987; Abler, 1989). These "alliance partners" might logically follow similar PAC contribution strategies. However, Grier and Munger (1986) asserted that labor unions and corporations allocate their contribution resources to very different types of legislators: "Specific legislative assets clearly have different values to different interest groups." Phase III identified these intragroup differences between the sheep industry and other agricultural PACs. This task was accomplished by using simple significance levels. For each industry, any β coefficient with a p-value less than 0.10 was coded as a targeted legislative attribute. The results of each industry segment were compared with the TOBIT results of a total agriculture aggregate (AGTOT) and an animal production aggregate (STOCK). In addition, the results of the sheep industry PAC category were compared to other individual animal production PAC categories. If the sheep producer category and its comparison category or aggregate returned the same significant targeted attributes, the agreement areas were labeled "same," as listed in Table 2.

Results and Discussion

Phase I

The TOBIT analysis revealed that only agriculture committee and percent farmland were significant determinants of sheep industry PAC strategies. The remaining variables – political party, legislator ideology, electoral security, agriculture appropriations subcommittee membership, environment and public works committee membership, finance committee membership, commerce committee membership, labor committee membership – were determined to be unimportant to sheep industry PAC decision makers.

Membership on the agriculture committee was found to be the most significant determinant of sheep industry PAC contributions. The AGCOM variable yielded a β coefficient of 488.47 with a p-value of 0.0001. Therefore, Senators serving on the agriculture committee could expect an ***annual*** sheep industry PAC contribution that was $488.47 higher than their nonmember counterparts. Membership on the agriculture committee equates to an additional $2,930.82 of sheep industry PAC money per re-election bid.

This conclusion is consistent with the research of Evans (1988) and Grier and Munger (1986, 1991). Grier and Munger's econometric analysis (1991) concluded: "(Interest) groups make significantly larger contributions to legislators on committees with jurisdiction over especially relevant policy issues." However, the results for the agriculture committee were inconsistent with Gopoian (1984), J. Wright (1985), Grier and Munger (1993) and Gardner (1995), who found no correlation between jurisdictional committee membership and PAC activity. These differing conclusions may be attributed to variation in time phase and industry studied.

The Senate agriculture committee has jurisdiction over the authorization of a preponderance of agricultural legislation. Targeting this committee may be beneficial because most of the amendments and mark-ups of agricultural legislation occur in committee, not on the Senate floor. Furthermore, proposed legislation can more easily be "killed" in committee by convincing the chairperson or a majority of the committee to not report a bill out of committee. Agricultural interests can also more easily communicate their messages in committee through public testimony and by concentrating resources on convincing a smaller number of people.

The percentage of a state considered farmland was another significant determinant of sheep industry PAC behavior. The STFarmP variable yielded a β coefficient of 4.83 with a p-value of 0.03. β Coefficients represent the expected amount of annual PAC contributions from sheep interest groups per state farmland percentage point. For example, a legislator from the largest sheep producing state, Texas, with a state farmland percentage of 77.3% would be expected to receive $334.24 more annually than a New Hampshire senator (8.1%). During the time period between elections, the Texas senator would be expected to raise $2,005.42 more from the sheep industry than his New Hampshire counterpart based solely on state farmland percentage.

These conclusions are similar to those of Gopoian (1984), Denzau and Munger (1986), Evans (1988) and Grier and Munger (1991). Reactions of legislators' constituencies affect their ability to vote with interest group positions. In this context, agricultural PACs give less to legislators from nonagricultural states because these legislators are less likely to vote pro-agriculture due to constituency concerns.

J. Wright (1989) suggested that PAC contributions targeted at "home state" legislators may simply be used as a reminder to legislators of the economic importance of an industry to a particular state, or the contribution may be used to elevate messages of lobbyists who represent particular constituent interests.

Phase II

Utilizing the results from Phase I and the categorization model specified by Evans (1988), the strategies and goals of sheep industry PACs is evident. The sheep industry met both qualifications of an access-seeking PAC – targeting members of a key committee and Senators' from states highly dependent on agriculture. In fact, the variables denoting access-seekers were the only attributes targeted by sheep PACs. Sheep interests were interested in gaining access to legislators and their staffs.

This categorization agrees with the traditional wisdom that interest groups cannot exercise political influence without an open door to legislative offices. If lobbyists do not have open communication channels with legislators and staff, how can the sheep industry's positions on issues be heard and represented?

The results are consistent with J. Wright (1985) who suggested that PACs possibly influence how members of Congress allocate their limited staff resources. However, the findings of this study are inconsistent with Gopoian (1984) who concluded that interest groups do not focus on strategies to maximize either access to a congressional staff or accumulation of power.

Phase III

Phase III compares sheep industry PAC behavior to PAC strategies of the agriculture industry and its individual livestock industry segments. An aggregation of all agricultural industry PAC contributions and a livestock industry contribution aggregate were used as bench marks for comparison. Sheep industry results were also compared to the contribution strategies of the individual livestock industry segments: milk and dairy

Table 2. Comparison of sheep and wool producer PAC strategies to other agricultural PAC strategies.[a]

Comparative Agricultural Sector	Party	Ideology	Seniority	State Farm %	Agriculture Committee	Agriculture Appropriations	Environment & Public Works	Finance	Commerce	Labor & Human Resources	Electoral Margin	Ideology^2	Seniority^2	Seniority by Agriculture Comm. Interaction
Agriculture Aggregate	–	–	–	*same*	*same*	–	*same*	*same*	*same*	*same*	–	*same*	*same*	*same*
Livestock Aggregate	–	–	–	*same*	*same*	–	*same*	*same*	*same*	*same*	–	*same*	*same*	*same*
Milk & dairy producers	–	–	–	*same*	–	–	*same*	*same*	*same*	*same*	–	*same*	*same*	–
Poultry and eggs	–	–	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*
Beef, Pork & Horse Interests	*same*	–	–	*same*	*same*	–	*same*	*same*	*same*	*same*	–	*same*	*same*	*same*
Feedlots	*same*	–	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*	*same*

[a] "Same" denote that the sheep and wool PAC strategies were the same in regard to all independent variables as the sector/subsector to which it was compared.

producers; poultry and egg producers; beef, pork and horse interests; and feedlots. Results from these comparisons are presented in Table 2.

Sheep industry PACs appear to follow a fairly nonconcerted effort in their contribution strategies. Comparing sheep industry PAC behavior to the rest of the agricultural industry (agriculture aggregate) revealed five disagreement areas. Comparison of sheep and wool producer PAC strategies to the aggregation of all livestock industry PAC expenditures yielded the same result.

A closer look at the individual livestock sectors reveals many different levels of agreement within the livestock industry. The sheep industry's PAC philosophy appears to be most similar to the strategies of feedlot related PACs (92.9% agreement) and poultry industry PACs (85.7% agreement). Conversely, sheep and wool PACs were least ideologically aligned with milk and dairy producer PACs with only a 50% agreement rate.

The independent variable with the most disagreement between sheep PACs and other agricultural PACs was ideology. While the other agricultural PAC strategy indicators showed a preference for conservative legislators, sheep and wool PACs showed no predisposition toward a particular ideology. In contrast, all agricultural PAC categories targeted legislators from states with a significant percentage of farm land.

These findings are consistent with Gopoian (1984) who asserted: "Economic interests are motivated by a variety of goals and that the generic treatment of ... PACs (in PAC research) masks the diverse orientations of individual PACs." Nonconcerted behavior among agricultural PACs is probably best explained by differences in PAC goals and personnel. As the power of agricultural groups continues to atrophy, closer coordination between agricultural PACs may warrant investigation.

Conclusions

As the number of sheep producers decline and U.S. sheep and wool production decreases, the sheep industry's political power is likely to erode. One way to stifle this erosion of influence is through an increased commitment to political activity and a more efficient PAC strategy. Before measures can be taken to achieve these goals, sheep producers and other industry participants must analyze and understand the current strategies of sheep industry PACs. This analysis fills the void by evaluating sheep industry PAC strategies over a six-year period.

The analysis was divided into three phases. Phase I revealed that sheep and wool producer PACs targeted contributions toward *senators from highly agricultural dependent states who served on the Committee on Agriculture, Nutrition and Forestry*. The targeting of only two legislative attributes represents a fairly narrow PAC contribution strategy.

The tendency toward interaction with representatives of highly agricultural states demonstrates the effect of constituency on PAC behavior. Senators from states with voters who are sympathetic or indifferent to an interest group's agenda will be more likely to vote for the interests of that group. Further, these contributions may be used to elevate the messages of lobbyists who represent constituents' concerns.

The agriculture committee is the committee of jurisdiction for a majority of agricultural issues. Membership on this committee carries a variety of political assets including receipt of more PAC funding from interest groups such as the sheep industry.

Surprisingly, many factors found to be important determinants of PAC contributions in the previous literature were determined to be insignificant determinants of sheep industry PAC behavior. Most notably, sheep and wool PAC officials showed no partisan preferences in their PAC contribution strategies and no affiliation with a particular ideology: neither conservatism nor liberalism. Interest groups can rarely be blatantly partisan. Even if their party of preference is in the majority, being able to convince 100% of a political party to vote for an issue is often a daunting task.

Considering that sheep PACs showed little increased financial commitment to close election races it can be deduced that sheep PACs follow a very cautious strategy, investing in only those who are likely to be winners. This cautious strategy explains why sheep PACs rarely invest in uncertain challengers or in primary elections. The sheep industry's cautious, narrow strategy may be a result of the limited amount of available PAC funds. Comparing the sheep and wool PAC category to the four other livestock categories utilized in Phase III, sheep industry PACs have the least amount of funding.

Phase II concluded that sheep and wool producer PACs were attempting to gain access to legislators and their staff with their PAC investments. Access provides an "open door" for lobbyists to convey sheep industry views, positions and concerns. If a legislator does not receive these lobbying messages, making informed decisions that are agreeable with sheep interests becomes a challenge. When a legislator receives hundreds of letters and phone calls per day, the extra access provided by sheep industry PACs may be the difference between getting noticed and being overlooked. While an access-seeking strategy does not guarantee a legislator will vote with sheep industry positions, it does help ensure that the industry's views will at least be heard and considered.

Phase III completed the analysis by identifying the intragroup differences between sheep industry PAC strategies and other livestock and agricultural PAC philosophies. The comparative analysis concluded that little coordination was apparent between the various segments of the livestock and other agricultural industries. With farm families comprising less than 2% of the U.S. population, increased coordination between various agricultural PACs may ensure that agricultural PAC money is more effectively invested. Economic realities may demand that coalitions between agricultural PACs become as commonplace as coalitions between farm groups.

If sheep producers are intent on retaining or even increasing their political presence in Washington, DC, it is imperative that sheep industry officials learn from past PAC activity and devise an action plan for future PAC involvement.

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Consumer Evaluation of Cuts from Normal and Callipyge Lambs

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Summary

Forty-eight lambs expressing the callipyge gene and 48 lambs possessing normal muscling were slaughtered at the University of Wyoming meat laboratory. Fat depths, longissimus muscle areas and carcass weights were recorded. Carcasses were aged approximately 20 days and then fabricated into retail cuts which were packaged and frozen. One package of loin chops, arm chops and leg roasts from each carcass had a customer survey form attached so that fat content, flavor, tenderness and customer repurchase intentions could be evaluated. Customers were instructed to complete the survey forms for the normal or callipyge lamb they purchased and mail them to the Animal Science Department at the University of Wyoming. Lambs expressing the callipyge phenotype produced heavier carcasses ($P < 0.05$) with less fat ($P < 0.01$) and larger longissimus muscle areas ($P < 0.01$) than normal lambs. Consumers rated the loin chops from callipyge lambs tougher ($P < 0.01$) than those from normal lambs and repurchase intentions for callipyge loin chops were lower ($P < 0.01$). Tenderness of leg roasts and arm chops was unaffected by lamb phenotype. Callipyge loin chops were rated too lean by 18% of the consumers while 23% listed arm chops from normal lambs as too fat. Flavor of all cuts was similar for both lamb phenotypes. The major differences between meat from callipyge and normal lambs were the lack of tenderness in callipyge loin chops and excessive fatness in normal arm chops.

Key words: lamb, tenderness, consumer acceptability.

Introduction

Lambs expressing the callipyge gene have heavier carcass weights, higher dressing percentages, less fat, larger longissimus areas and more muscular legs than normal lambs (Field et al., 1996; Jackson et al., 1997). While these improved carcass characteristics enhance cutability, significant tenderness problems have been associated with cuts from the loin of callipyge lambs (Kerth et al., 1995; Koohmaraie et al., 1995; Field et al., 1996, 1997). These differences are of concern because tenderness is the most important palatability attribute of meat, and it has the greatest influence on a consumer's perception of meat quality (Dikeman, 1987).

The problem of loin tenderness associated with callipyge lambs prompted us to investigate consumer perceptions of the meat. The specific objectives of our study were: 1) to determine if consumers can detect a lack of tenderness throughout the callipyge carcass or if the problem is confined to the loin; 2) to determine what percentage of consumers consider specific cuts of meat from callipyge lambs as objectionably tough; and 3) to evaluate consumer intentions to repurchase lambs from the two phenotypes.

Materials and Methods

Forty-eight Columbia-type lambs expressing the callipyge gene and 48 Suffolk, Hampshire, Columbia or Rambouillet lambs possessing normal muscling were slaughtered at the University of Wyoming meat laboratory. The callipyge lambs were obtained from mating rams known to be carriers of the gene with ewes believed to be non-carriers. Phenotypic expression of muscle hypertrophy was subjectively scored as described by Field et al. (1997). Hot carcass weight, fat depths and longissimus areas were recorded. Carcasses were aged at 2 to 4 °C for approximately 20 days under conditions similar to those described by Field and Riley (1968) and then fabricated into the following bone-in retail cuts: arm, blade, rib, loin and sirloin chops cut 2.54-cm thick, leg roasts, shanks and spareribs. Cuts were trimmed so that subcutaneous fat depth was 0.5 cm or less and then packaged in plastic coated freezer paper and frozen at -30 °C.

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Three arm chops from the shoulder, four loin chops from the anterior half of the loin and an American leg roast from each carcass were identified as survey cuts. Survey forms containing the lamb number and name of cut were affixed to these three packages. Customers purchased one entire carcass including the survey cuts from the university abattoir without knowing that a study to compare callipyge and normal lambs was in progress. Most of the customers had purchased other frozen lambs from the meat laboratory prior to this survey. At the time of purchase, customers were given instructions for returning the questionnaires and requested to use the packages with survey forms attached first but they were not given any information about the specific lamb they had purchased. The survey form included questions on the customer's visual appraisal of leanness as well as their scores for flavor, tenderness and intent to repurchase (Figure 1). Follow-up phone calls to encourage the return of survey forms were made. Approximately 6 months after the last lambs were sold, questionnaires received from 40 to 46 of the customers purchasing the three different cuts were tabulated and analyzed using the GLM procedure of SAS (1985). Therefore, completed questionnaires were received from 83 to 96% of the customers purchasing callipyge or normal lambs.

Results and Discussion

Carcass characteristics of normal and callipyge lambs are presented in Table 1. Callipyge carcasses were slightly heavier and substantially leaner and more muscular ($P < 0.01$) than normal lambs. Extensive muscle hypertrophy in the rib, loin and leg along with reduced fat levels in callipyge lambs have been reported by others (Koohmaraie et al., 1995, 1996; Carpenter et al., 1996; Jackson et al., 1997).

Results of consumer evaluations of retail cuts from callipyge and normal lambs are presented in Table 2. While most customers were satisfied with leanness of the loin chops, 18% rated loin chops from callipyge lambs too lean and 9% rated loin chops from normal lambs too fat. Customers rating leg roasts about right in leanness made up 88 and 87% of the replies for normal and callipyge lambs, respectively. However, 10% of those scoring leg roasts from normal lambs thought they were too fat while 13% thought callipyge leg roasts were too lean. Differences between means within cuts were significant ($P < 0.01$) for the loin, leg and arm cuts. From a leanness standpoint, callipyge carcasses produced arm chops with more consumer appeal than did carcasses from normal lambs because normal arm chops were rated too fat by 23% of the respondents when compared to 5% for callipyge arm chops. The difference in intermuscular fat between the ribs and the pectoral muscle of arm chops was probably the reason for more desirable ratings ($P < 0.01$) for callipyge arm chops. Our findings that leaner arm chops are more desirable than fatter arm chops confirms the work of Jeremiah et al. (1993) who reported that consumers select against fat when purchasing lamb chops. Ward et al. (1995) also found that reducing fat content of lamb cuts was an important factor in improving consumer perceptions.

Flavor of meat from loin chops, leg roasts and arm chops was unaffected ($P < 0.05$) by lamb phenotype in agreement with Kerth et al. (1995) who failed to find flavor differences between lamb chops of normal and callipyge lambs. Shackelford et al. (1997) scored flavor intensity of leg muscles from normal and callipyge lambs and they also concluded that no differences ($P > 0.05$) existed. However, Carpenter et al. (1997) found less desirable flavor ratings for callipyge chops that came from electrically stimulated and calcium chloride-injected carcasses. The lower scores in this later study probably resulted from use of an untrained consumer panel that may have allowed lower tender-

Figure 1. Lamb questionnaire.

Customer Name: ____________________

Lamb Number: _____ Leg _____ Arm Chop _____ Loin Chop _____

Please check if: Too Lean _____, About Right _____, Too Fat _____.

Was the flavor: Very Good _____, Good _____, Fair _____, Poor _____.

Was the meat: Tender _____, Neither Tough nor Tender _____, Tough _____.

Would you purchase lamb of this quality again? Yes _____ No _____

Additional comments concerning flavor, juiciness, texture, color or overall acceptability would be appreciated.

NOTE: *Different types of lamb are being compared.*
Please return this questionnaire to the address on reverse side.

Table 1. Means for characteristics of normal lambs and lambs expressing the callipyge gene.

Item	Phenotype: Callipyge	Phenotype: Normal	SE	P-value
Hot carcass weight, kg	30.18	29.42	0.27	0.02
Fat depth, cm	0.38	0.70	0.02	0.01
Longissimus area, cm^2	24.51	17.42	0.47	0.01

ness and juiciness scores to influence their scores for flavor.

Only 46% of those who purchased callipyge lambs aged 20 days rated the loin chops as tender, while 27% considered them tough (Table 2). In contrast, normal loin chops were rated tender by 85% of respondents and tough by 9%. Because loin chops are the highest priced cut from the lamb carcass, customers expect this cut to combine the attributes of tenderness, juiciness and flavor for a quality eating experience. The lack of tenderness in loin chops from callipyge lambs and the more acceptable tenderness ratings for callipyge leg roasts supports the findings of Shackelford et al. (1997). The latter researchers showed that differences in shear force values were much greater for longissimus muscles of callipyge when compared to normal lambs than were differences in leg muscles. In addition, Shackelford et al. (1997) found that roasting improved tenderness of leg muscles from callipyge lambs more than it did leg muscles of normal lambs. When compared to loin chops and leg roasts, arm chops are considered the toughest cut so it is interesting that arm chops from callipyge lambs were given more desirable tenderness ratings than were callipyge loin chops.

Customers who purchased loin chops from normal lambs were more likely to repurchase than customers who purchased loin chops from callipyge lambs (Table 2). If "positive repurchase intentions" in this study are compared to the category of "rated acceptable" in the study conducted by Kerth et al. (1995), the overall acceptance of callipyge and normal loin chops from both studies is nearly identical. In fact, 91% of the respondents in the current study stated they would repurchase normal loin chops when compared to 92% in the study by Kerth et al. (1995). Callipyge loin chops were rated acceptable by 77% in the current study and by 79% in the Kerth et al. (1995) study. In the current study, all customers who said they would not purchase callipyge lambs again rated the loin chops as tough. Intent to repurchase leg roasts and arm chops was unaffected by lamb phenotype and tenderness ratings were not closely correlated with the decision to purchase again. Kerth et al. (1995) also found high consumer satisfaction levels for leg roasts from callipyge lambs.

Table 2. A summary of consumer evaluations of cuts from normal lambs and from lambs expressing the callipyge gene.

	Lamb phenotype for loin chops			Lamb phenotype for leg roasts			Lamb phenotype for arm chops		
Item	Normal	Callipyge	P-value[a]	Normal	Callipyge	P-value	Normal	Callipyge	P-value
Number of replies	46	44	–	41	45	–	44	40	–
Leanness, %[b]									
Too lean	0	18	–	2	13	–	0	2	–
About right	91	82	–	88	87	–	77	93	–
Too fat	9	0	–	10	0	–	23	5	–
Mean score[c]	2.09	1.82	0.01	2.07	1.87	0.01	2.23	2.02	0.01
Flavor, %[b]									
Very good	63	55	–	71	76	–	55	58	–
Good	26	30	–	19	18	–	34	35	–
Fair	11	11	–	9	2	–	9	2	–
Poor	0	4	–	0	4	–	2	5	–
Mean score[d]	1.48	1.66	0.26	1.39	1.36	0.83	1.59	1.55	0.80
Tenderness, %[b]									
Tender	85	46	–	88	80	–	73	68	–
Neither	6	27	–	12	18	–	18	25	–
Tough	9	27	–	0	2	–	9	7	–
Mean score[e]	1.24	1.82	0.01	1.12	1.22	0.45	1.36	1.40	0.78
Repurchase, %[b]									
Yes	91	77	–	93	91	–	82	90	–
No	9	23	–	7	9	–	18	10	–
Mean score[f]	1.09	1.23	0.04	1.07	1.09	0.82	1.18	1.10	0.26

[a] P-value from GLM procedure.
[b] Percentage of replies.
[c] Too Lean = 1, About Right = 2, Too Fat = 3.
[d] Very Good = 1, Good = 2, Fair = 3, Poor = 4.
[e] Tender = 1, Neither Tough nor Tender = 2, Tough = 3.
[f] Would Purchase Again = 1, Would Not Purchase Again = 2.

The final question on the survey form solicited additional comments from customers. Comments from customers purchasing normal lambs were generally favorable. However, typical responses received from customers purchasing callipyge lambs included: "tougher than expected," "strong flavor" and "dry." Comments indicating that callipyge lamb meat was dry supports work of Shackelford et al. (1997) who reported that regardless of cooking method, leg muscles from callipyge lambs were less juicy than those from normal lambs. Carpenter et al. (1997) attributed less desirable juiciness and flavor scores in callipyge chops when compared to normal chops to lower fat concentrations in callipyge longissimus. Clare et al. (1997) found that a phenotype × muscle interaction influenced juiciness scores. In their normal phenotypes initial juiciness was lower in the supraspinatus than in the longissimus muscle. However, if the muscles originated from callipyge lambs, the semitendinosus muscles were a 0.6 unit juicier than the other two muscles.

Conclusions

Muscle toughness, especially in the loin, can significantly influence the consumer's overall perception of lamb meat. Although callipyge lamb meat satisfies the demand for a leaner, healthier product, the problem of loin chop tenderness must be resolved before there will be industry-wide acceptance if the findings from our small group of customers reflect attitudes of today's consumers.

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The Influence of Lamb Chronological Age, Slaughter Weight and Gender on Consumer Acceptance[1]

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Summary

A total of 1,660 shank and 1,660 butt leg roasts were distributed to lamb-consuming households in 21 central Alberta regions for the evaluation of acceptability of specific palatability attributes. A total of 1,528 and 1,529 responses, respectively, were obtained for shank and butt roasts. Shank roasts from the mid-weight groups (40.5 to 67.7 kg) were rated highest in flavor, juiciness and overall palatability. Butt roasts from ewe lambs were more acceptable in flavor and overall palatability than their counterparts from rams and rams and wethers, respectively. However, these differences were only of marginal practical significance at best. Over 82% of all roasts were rated slightly acceptable or better in all palatability traits, less than 11% were rated slightly unacceptable or worse. The highest proportion of unacceptable ratings were for tenderness. However, over 10% of the shank roasts from rams up to 50 kg in slaughter weight and ewes up to 40.4 kg in slaughter weight were unacceptable in flavor. Roasts from rams consistently received the highest proportion of unacceptable ratings. A relatively high proportion (19.2%) of ewe shank roasts and ram butt roasts from lambs up to 40.4 kg at slaughter were unacceptable in juiciness, over 10% of all shank roasts from lambs under 58.9 and over 67.7 kg at slaughter were unacceptable in tenderness. In addition, over 11% of the shank roasts from rams up to 58.6 and wethers up to 40.4 kg at slaughter were unacceptable in overall palatability. Consequently, from a consumer acceptance standpoint based upon palatability, the most appropriate slaughter weights for market lambs is between 58.6 and 67.7 kg. However, it appears probable that this conclusion may be a function of an interactive effect of physiological maturity and fatness, rather than slaughter weight per se. Therefore, it does not appear prudent to control slaughter weight in a carcass grading system.

Key words: lamb, chronological age, slaughter weight, gender, consumer acceptance.

Introduction

Although Mendenhall and Erchanbrack (1979) reported the flavor of lamb from all genders slaughtered between 41 and 71 kg to be highly acceptable to consumers, Jeremiah et al. (1993) reported that the population of Canadian market lambs was too fat to satisfy the vast majority of consumers. In addition, significant differences in lamb palatability attributable to chronological age, slaughter weight and gender have been demonstrated (Jeremiah et al., 1997b), despite the fact that a considerable amount of controversy exists within the literature regarding the influences of these factors on lamb palatability. At least a portion of the inconsistency in reported findings is probably attributable to age/weight/gender interactions. Crouse (1983) concluded after reviewing the literature that gender × slaughter weight interactions exerted important influences upon lamb palatability. However, very few studies have attempted to determine the influence of chronological age, slaughter weight and gender on the consumer acceptance of lamb. The present study was designed to provide such an evaluation.

Materials and Methods

A total of 1,660 lambs were selected on the basis of age, slaughter weight, gender and fatness to fill specific subclasses in an experimental design grid (Jeremiah et al., 1997a). The lambs evaluated were a representative sample of the entire range of lambs

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currently being marketed in Canada, rather than a set of animals of controlled breeding and dietary management, slaughtered at different weights and/or ages. The lambs in the present study were purchased from commercial sheep producers with breeding records and certified birthdates for the lambs purchased, so that both the breeding and chronological ages could be ascertained. The lambs were predominantly crossbreds, involving some combination of the following breeds: Cheviot, Columbia, Dorset, Finnish Landrace, Hampshire, Leicester, Montadale, Rambouillet, Romanoff, Romney, Shropshire, Southdown, Suffolk, Targhee and/or Texel. Breeds and breed-crosses were allocated as evenly as possible among age/weight/gender subclasses and care was taken to prevent a given breed or breed-cross from constituting a majority in any given age/weight/gender subclass.

Fatness and gender were ascertained the day prior to slaughter. Fatness was ascertained both subjectively by a trained, experienced evaluator and ultrasonically; the same fatness criteria were applied to all age/slaughter weight/gender subclasseses. Breed composition necessarily varied among age/slaughter weight subclasses, but was relatively constant within subclasses. Since the lambs were purchased from different producers, it is possible they were fed differently; it is also possible this may have influenced compositional properties. The actual frequency distribution of lambs evaluated has been presented (Jeremiah et al., 1997a) by age, weight, gender and fatness subclass.

All lambs were slaughtered at the Lacombe Meat Research Centre in Alberta, Canada, under simulated commercial conditions. At 24 hours postmortem, the right side of each carcass was separated into wholesale cuts. The legs were then subdivided into shank and butt portions (halves), identified with metal tags, vacuum-packaged, frozen at -30 °C in still air and stored at that temperature until distributed to consumers for evaluation.

A total of 3,320 lamb leg roasts (1,660 shank, 1,660 butt) were distributed to lamb-consuming households in 21 central Alberta regions for evaluation of acceptability of flavor, juiciness, tenderness and overall palatability. Each household received either two shank or two butt roasts free of charge. The households were chosen at random from the telephone directories, without regard to demographic information regarding income level, age of individuals in the household, etc.

A total of 1,528 and 1,529 responses were obtained for shank and butt leg roasts, respectively. Between 1 and 15% of the responses were obtained from each region. It was the intent that households participating in the study should be at least occasional lamb consumers and it was not the first time lamb was consumed by 96.5 and 95.8% of the respondents who had received shank and butt roasts, respectively. However, 92.4 and 91.5% of the respondents who received shank and butt roasts, respectively, were infrequent consumers of lamb (two to three times per month or less).

Consuming households were instructed to prepare the roasts which they received using the method they normally employed for preparation of lamb leg roasts, but to record the cooking methods and times employed and to evaluate and record the degree of doneness at the point of consumption. The vast majority of consumers cooked their roasts by oven roasting after thawing (83.3%). Also, most consuming households cooked their roasts for 60 to 120 minutes (56.9%) and to a medium to well done degree of doneness (90.85%). Following preparation, each household was asked to reach a consensus rating for the acceptability of the flavor, juiciness, tenderness and overall palatability of the roasts which they received using a five-point hedonic scale (1 = dislike extremely; 5 = like extremely).

Data were initially analyzed using a full model for analysis of variance by GLM. The model was:

y = A + W + G + 2-way interactions + 3-way interactions + processing treatment + cooking method + degree of doneness + cooking time.

Where:
A = age;
W = weight; and
G = gender.

Since processing treatment, cooking method, degree of doneness and cooking time generally did not affect consumer ratings ($P > 0.05$), these effects were safely ignored and the data were reanalyzed using a reduced model which was:

y = A + W + G + 2-way interactions + 3-way interactions.

The only significant ($P < 0.05$) three-way interaction was for the tenderness acceptability of shank roasts. Moreover, inclusion of three-way interactions in the model created problems of estimability as a result of some age/weight/sex subclasses being missing. Therefore, the data were again reanalyzed using a further reduced model without three-way interactions:

y = A + W + G + 2-way interactions.

Since lambs within age group 2 (6 to 9 months of age) and within weight groups 2 through 5 (40.5 to 76.8 kg liveweight) were subjected to three separate processing treatments (conventional, electrically stimulated, electrically stimulated/hot-boned) the data were reanalyzed to evaluate the effects of these treatments on consumer acceptance of certain palatability traits. Analysis of variance were performed using the following model:

y = G + W + T + 2-way interactions + 3-way interactions.

Further examination of the data revealed the significant two-way interactions were due to very small numbers of responses in certain subclasses. Therefore, the data were pooled and reanalyzed to examine only the influence of the main effects on the acceptability of palatability attributes. The effects of chronological age, slaughter weight and gender will be discussed here and the effects of processing treatment will be discussed in a subsequent manuscript. In addition, the percent unacceptable (consumers ratings ≤ 2.49) scores for each palatability trait in each subclass were tabulated.

Results and Discussion

Although no significant ($P < 0.05$) trends were observed in the acceptability of any of the palatability traits with increasing age or weight, significant ($P < 0.05$) differences were observed among age groups in the acceptability of palatability traits of shank roasts and in the flavor acceptability of butt roasts (Table 1). The acceptability of flavor, juiciness and overall palatability of shank roasts was rated higher ($P < 0.05$) when they were from lambs in weight groups 2, 3 and 4 (slaughter weights between 40.5 and 67.7 kg) than when they were from lighter or heavier lambs (Table 2). It should be kept in mind, however, that the magnitude of these differences were less than one full unit. Therefore, they represent differences with marginal practical significance at best. Present consumer results are in agreement with previous laboratory panel findings on meat from the same animals: that meat from animals in the mid-age (6 to 12 months) and mid-weight (40.4 to 67.7 kg live) groups was the most palatable (Jeremiah et al., 1997b). However, present results are contrary to previous reports from laboratory panel studies, that the desirability of lamb flavor decreased with age (Misock et al., 1976) and the flavor of older rams slaughtered at 68

Table 1. Least squares means and standard errors for consumer acceptability of palatability traits[a] by age group.

	Age group								
	1 (3 to 6 months)		2 (6 to 9 months)		3 (9 to 12 months)		4 (12 to 15 months)		
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Probability
Shank:									
Flavor	3.88[b]	0.18	4.31[c]	0.10	4.46[c]	0.10	3.67[b]	0.20	0.0006
Juiciness	3.74[b]	0.18	4.28[c]	0.11	4.31[c]	0.11	3.67[b]	0.20	0.0038
Tenderness	3.78[b]	0.19	4.25[c]	0.12	4.44[c]	0.12	3.57[b]	0.22	0.0007
Overall	3.64[b]	0.18	4.28[c]	0.11	4.43[c]	0.11	3.61[b]	0.20	0.0001
Butt:									
Flavor	3.92[b]	0.17	4.56[c]	0.12	4.36[c]	0.13	4.54[c]	0.19	0.0193
Juiciness	4.16	0.19	4.45	0.13	3.99	0.14	4.17	0.21	0.1097
Tenderness	4.21	0.21	4.51	0.15	4.03	0.15	4.01	0.23	0.0905
Overall	4.22	0.18	4.55	0.13	4.18	0.13	4.13	0.20	0.1275

[a] Rated on a five-point hedonic scale: 5 = like extremely; 1 = dislike extremely.

[b,c] Means in the same row without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

Table 2. Least squares means and standard errors for consumer acceptability of palatability traits[a] by slaughter weight group.

	Slaughter weight group										
	1 (31.8 to 40.4 kg)		2 (40.5 to 49.5 kg)		3 (50.0 to 58.6 kg)		4 (58.9 to 67.7 kg)		5 (68.2 to 76.8 kg)		
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Probability
Shank:											
Flavor	3.43[b]	0.28	4.28[c]	0.11	4.45[c]	0.04	4.47[c]	0.04	3.78[b]	0.22	0.0001
Juiciness	3.45[b]	0.29	4.22[c]	0.12	4.28[c]	0.04	4.31[c]	0.05	3.74[b]	0.23	0.0061
Tenderness	3.35[b]	0.31	4.14[b,c]	0.12	4.31[c]	0.05	4.45[c]	0.05	3.81[b]	0.24	0.0001
Overall	3.45[b]	0.29	4.26[c]	0.12	4.33[c]	0.04	4.40[c]	0.05	3.49[b]	0.23	0.0001
Butt:											
Flavor	4.70	0.30	4.40	0.11	4.38	0.04	4.43	0.04	3.83	0.21	0.0676
Juiciness	4.00	0.33	4.25	0.12	4.22	0.04	4.25	0.05	4.24	0.23	0.9509
Tenderness	4.01	0.36	4.10	0.13	4.26	0.05	4.31	0.05	4.27	0.26	0.5695
Overall	4.21	0.32	4.25	0.12	4.30	0.04	4.33	0.05	4.26	0.22	0.9674

[a] Rated on a five-point hedonic scale: 5 = like extremely; 1 = dislike extremely.

[b,c] Means in the same row without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

kg was less desirable than the flavor of younger rams slaughtered at 41 kg (Field et al., 1978). However, present results substantiate earlier findings that the correlation between chronological age and the desirability of lamb flavor, as assessed by a laboratory panel, was very low and there were no significant trends in the desirability of lamb flavor with advancing age based upon laboratory panel assessments (Misock et al., 1976). In addition, the results from shank but not butt roasts support previous observations that the flavor of both ewes and wethers, as assessed by a laboratory panel, became more desirable as slaughter weight increased from 36 to 54 kg (Kemp et al., 1976).

Significant ($P < 0.05$) differences among gender groups were observed only in the acceptability of flavor and overall palatability of butt roasts (Table 3). The flavor of butt roasts was rated more acceptable when from ewes than from rams and the overall palatability of butt roasts was rated more acceptable when from ewes than from rams or wethers ($P < 0.05$). However, these differences had a magnitude less than half a unit and therefore should be considered to be of no practical importance. These consumer findings are, however, consistent with previously reported panel evaluations indicating meat from ewes had the most appropriate, well balanced and well blended flavor (Jeremiah et al., 1997c).

Although Field et al. (1982) reported consumers were divided on their response to intense lamb flavor, results from the present study support the previous conclusion of Mendenhall and Erchanbrack (1979) that the flavor of rams, ewes and wethers slaughtered between 41 and 71 kg was highly acceptable to consumers. However, present results are contrary to a previous report that wethers had a more desirable flavor than ewes (Jacobson et al., 1962). In addition, present results from butt roasts but not shank roasts support other reports that rams had a less desirable flavor than wethers (Kemp et al., 1972; Misock et al., 1976; Pattie et al., 1964).

The proportion (percent) of responses by consumer acceptance scores for various palatability traits is presented in Table 4. Over 82% of the consuming households rated the roasts which they received as slightly acceptable or better (≥ 4.00) in all palatability traits while less than 11% of the respondents rated the roasts which they received as slightly unacceptable or worse (≤ 2.0). A higher proportion of the roasts were rated unacceptable for tenderness than for any other palatability trait. Over 10% of the shank roasts from rams up to 50 kg liveweight and ewes up to 40.4 kg liveweight were rated unacceptable in flavor (Table 5); and roasts from rams consistently received the highest proportion of unacceptable ratings. Although these results provide some support for the conclusion that the flavor of rams, ewes and wethers slaughtered between 41 and 71 kg was highly acceptable in flavor (Mendenhall and Erchanbrack, 1979), they also support other observations that the flavor of both ewes and wethers became more desirable as slaughter weight increased from 36 to 54 kg (Kemp et al., 1976). Rams were less desirable in flavor than wethers (Kemp et al., 1972; Misock et al., 1976; Pattie et al., 1964), the flavor of wethers was more desirable than that of ewes (Jacobson et al., 1962) and rams were less desirable in flavor than wethers to a slaughter weight of 45 kg (Misock et al., 1976). However, these results are in disagreement with reports that flavor was less desirable in older 68-kg rams than in younger

Table 3. Least squares means and standard errors for consumer acceptability of palatability traits[a] by gender.

	Ram		Ewe		Wether		
Variable	Mean	SE	Mean	SE	Mean	SE	Probability
Shank:							
Flavor	4.01	0.08	4.12	0.08	4.10	0.09	0.2225
Juiciness	3.97	0.09	3.99	0.09	4.03	0.09	0.6643
Tenderness	4.03	0.09	4.06	0.09	3.95	0.10	0.2955
Overall	3.92	0.09	4.06	0.09	3.99	0.09	0.1386
Butt:							
Flavor	4.26[b]	0.09	4.44[c]	0.08	4.35[b,c]	0.09	0.0213
Juiciness	4.13	0.09	4.26	0.09	4.19	0.10	0.1943
Tenderness	4.17	0.10	4.28	0.10	4.12	0.11	0.0959
Overall	4.21[b]	0.09	4.37[c]	0.09	4.23[b]	0.09	0.0406

[a] Rated on a five-point hedonic scale: 5 = like extremely; 1 = dislike extremely.

[b,c] Means in the same row without a superscript or bearing a common superscript do not differ significantly ($P > 0.05$).

Table 4. Percent[a] distribution of samples by various consumer acceptance scores.

	Flavor		Juiciness		Tenderness		Overall	
Score[b]	Shank	Butt	Shank	Butt	Shank	Butt	Shank	Butt
1	0.79	1.05	0.52	0.33	1.05	0.98	0.79	0.85
2	4.52	3.34	4.97	6.41	6.74	9.68	6.02	4.64
3	6.41	7.00	12.83	10.86	8.31	7.00	6.28	8.83
4	32.53	32.37	32.92	35.91	27.16	28.38	34.23	34.60
5	55.76	56.25	48.76	46.50	56.74	53.96	52.68	51.08
Total	1,528	1,529	1,528	1,529	1,528	1,529	1,528	1,529

[a] Expressed as a percentage of the column total.

[b] Consumer scores: 1 = unacceptable; 2 = slightly unacceptable; 3 = neither acceptable nor unacceptable; 4 = slightly acceptable; 5 = acceptable.

41-kg rams (Field et al., 1978) and flavor desirability decreased with age at heavier weights (Misock et al., 1976). A relatively large proportion (19.23%) of the shank roasts from ewes and butt roasts from rams up to 40.4 kg liveweight were rated unacceptable in juiciness and over 11% of all roasts from lambs up to 40.4 kg in slaughter weight were rated unacceptable in juiciness (Table 6). Over 10% of all shank roasts were rated unacceptable in tenderness when they were from lambs under 58.9 kg and over 67.7 kg in slaughter weight (Table 7). Over 11% of the shank roasts from rams up to 58.6 kg liveweight and from wethers up to 40.4 kg liveweight were rated unacceptable in overall palatability; and over 11% of the butt roasts from rams up to 40.4 kg in liveweight were rated unacceptable in overall palatability (Table 8).

Conclusions

Careful consideration of these findings gives a clear indication from a consumer acceptance standpoint, based upon palatability, that the most appropriate slaughter weights to market lambs is between 58.6 and 67.7 kg. However, it appears probable that this conclusion may be a function of an interactive effect of physiological maturity and fatness rather than slaughter weight per se. Therefore, it does not appear prudent to control slaughter weight in a carcass grading system.

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Table 5. Percent unacceptable flavor scores (scores 1 and 2) by roast type/age/gender/weight subclass.

		Shank				Butt			
Age group[a]	Slaughter weight group[b]	Ram	Ewe	Wether	All	Ram	Ewe	Wether	All
1	1	13.04	8.33	4.00	8.33	4.35	0.00	0.00	1.33
	2	7.14	8.33	3.85	6.41	10.71	4.55	0.00	5.33
	3	6.90	0.00	4.76	3.66	10.71	6.25	4.71	7.14
	4	11.54	4.53	0.00	5.71	8.33	0.00	0.00	3.03
	All	10.28	4.85	3.23	6.27	9.62	2.94	1.05	4.65
2	2	11.43	6.98	0.00	5.60	8.11	2.27	6.38	5.47
	3	6.98	0.00	0.00	2.34	7.50	5.13	4.08	5.47
	4	5.13	7.32	10.53	7.63	4.88	0.00	0.00	1.69
	5	0.00	9.09	6.06	5.05	11.11	2.94	5.88	6.73
	All	5.92	5.77	3.64	5.07	7.74	2.52	4.22	4.79
3	2	11.76	8.57	3.03	7.84	3.13	0.00	0.00	0.99
	3	2.44	2.56	4.88	3.31	16.28	2.56	4.76	8.06
	4	2.44	0.00	6.06	2.68	5.13	2.78	3.13	3.74
	5	3.03	3.03	2.94	3.00	6.45	6.45	2.94	5.21
	All	4.64	3.45	4.23	4.11	8.16	2.86	2.80	4.65
4	3	3.23	3.23	0.00	2.08	0.00	0.00	2.94	1.03
	4	9.09	11.43	2.94	7.84	2.94	8.82	5.88	5.88
	5	6.45	5.56	11.36	8.11	0.00	2.78	4.65	2.63
	All	6.25	7.62	5.31	6.37	0.98	3.85	4.46	3.14
All	1	11.11	11.54	3.85	8.86	3.85	0.00	0.00	1.25
	2	10.20	7.69	1.87	6.47	7.14	1.96	2.78	3.90
	3	4.68	1.43	2.10	2.81	9.09	3.55	4.03	5.54
	4	6.47	5.84	5.56	5.97	5.07	2.99	2.48	3.56
	5	4.08	5.88	7.21	5.79	6.80	3.96	4.50	5.08
	All	6.52	5.30	4.09	5.30	6.89	2.97	3.29	4.38

[a] Age group: 1 = 3 to 6 months; 2 = 6 to 9 months; 3 = 9 to 12 months; 4 = 12 to 15 months.

[b] Slaughter weight group: 1 = 31.8 to 40.4 kg.; 2 = 40.5 to 49.5 kg.; 3 = 50.0 to 58.6 kg.; 4 = 58.9 to 67.7 kg.; 5 = 68.2 to 76.8 kg.

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Table 6. Percent unacceptable juiciness scores (scores 1 and 2) by roast type/age/gender/weight subclass.

Age group[a]	Slaughter weight group[b]	Shank				Butt			
		Ram	Ewe	Wether	All	Ram	Ewe	Wether	All
1	1	8.70	16.67	8.00	11.11	17.39	8.00	7.41	10.67
	2	3.57	12.50	0.00	5.13	7.14	0.00	8.00	5.33
	3	3.45	12.50	9.52	8.54	3.57	6.25	8.33	5.93
	4	7.69	4.35	4.76	5.71	12.50	8.70	5.26	9.09
	All	6.54	11.65	5.38	7.92	9.62	5.88	7.37	7.64
2	2	8.57	4.65	6.38	6.40	13.51	2.27	10.64	8.59
	3	6.98	0.00	2.13	3.13	5.00	5.13	0.00	3.13
	4	2.56	4.88	10.53	5.93	7.32	9.76	5.56	7.63
	5	9.09	3.03	0.00	4.04	0.00	5.88	0.00	1.92
	All	6.58	3.21	4.85	4.86	6.45	5.66	4.22	5.42
3	2	5.86	11.43	0.00	5.88	3.13	11.76	11.43	8.91
	3	2.44	0.00	4.88	2.48	11.63	2.56	7.14	7.26
	4	2.44	2.63	9.09	4.46	0.00	2.78	9.38	3.74
	5	0.00	3.03	8.82	4.00	12.90	9.68	8.82	10.42
	All	2.65	4.14	5.63	4.11	7.48	6.43	9.09	7.67
4	3	9.68	3.23	8.82	7.29	15.63	6.45	5.88	9.28
	4	0.00	5.71	0.00	1.96	2.94	2.94	8.82	4.90
	5	9.68	8.33	6.82	8.11	11.43	2.78	4.65	6.14
	All	6.25	6.67	5.31	6.05	9.80	3.85	6.25	6.60
All	1	7.41	19.23	7.69	11.39	19.23	7.41	7.41	11.25
	2	6.12	8.65	2.80	5.83	8.16	4.90	10.91	7.79
	3	5.56	3.57	5.59	4.92	9.09	4.96	4.70	6.24
	4	2.88	4.38	6.35	4.48	5.07	5.97	7.44	6.11
	5	7.14	4.90	5.41	5.79	7.77	5.94	4.50	6.03
	All	5.34	5.89	5.26	5.50	8.07	5.54	6.59	6.74

[a] Age group: 1 = 3 to 6 months; 2 = 6 to 9 months; 3 = 9 to 12 months; 4 = 12 to 15 months.

[b] Slaughter weight group: 1 = 31.8 to 40.4 kg.; 2 = 40.5 to 49.5 kg.; 3 = 50.0 to 58.6 kg.; 4 = 58.9 to 67.7 kg.; 5 = 68.2 to 76.8 kg.

Table 7. Percent unacceptable tenderness scores (scores 1 and 2) by roast type/age/gender/weight subclass.

Age group[a]	Slaughter weight group[b]	Shank				Butt			
		Ram	Ewe	Wether	All	Ram	Ewe	Wether	All
1	1	13.04	16.67	24.00	18.06	17.39	12.00	18.52	16.00
	2	10.71	16.67	3.85	10.26	17.86	13.64	16.00	16.00
	3	6.90	6.25	9.52	7.32	10.71	3.13	8.33	7.14
	4	3.85	0.00	9.52	4.29	8.33	0.00	0.00	3.03
	All	9.35	9.71	11.83	10.23	13.46	6.86	11.58	10.63
2	2	17.14	11.63	17.02	15.20	10.81	13.64	8.51	10.94
	3	0.00	2.63	14.89	6.25	2.50	12.82	8.16	7.81
	4	0.00	7.32	2.63	3.39	4.88	7.32	5.56	5.93
	5	6.06	6.06	6.06	6.06	5.56	5.88	8.82	6.73
	All	5.26	7.05	10.91	7.82	5.81	10.06	7.83	7.92
3	2	11.76	2.86	3.03	5.88	9.38	8.82	17.14	11.88
	3	9.76	2.56	7.32	6.61	16.28	10.26	9.52	12.10
	4	4.88	7.89	12.12	8.04	7.69	2.78	12.50	7.48
	5	0.00	9.09	5.88	5.00	19.35	12.90	20.59	17.71
	All	6.62	5.52	7.04	6.39	13.61	8.57	14.69	12.23
4	3	19.35	6.45	8.82	11.46	12.50	9.68	17.65	13.40
	4	0.00	8.57	2.94	3.92	17.65	5.88	14.71	12.75
	5	6.45	0.00	11.36	6.31	17.14	8.33	9.30	11.40
	All	8.33	5.71	7.96	7.32	15.69	7.69	14.29	12.58
All	1	11.11	19.23	23.08	17.72	19.23	11.11	18.52	16.25
	2	13.27	9.62	9.35	10.68	12.24	11.76	13.89	12.66
	3	8.33	4.29	10.49	7.73	10.49	9.22	10.74	10.16
	4	2.16	6.57	6.35	4.98	9.42	4.48	9.09	7.63
	5	5.10	4.90	8.11	6.11	13.59	8.91	12.61	11.75
	All	7.11	6.88	9.36	7.79	11.61	8.51	11.82	10.66

[a] Age group: 1 = 3 to 6 months; 2 = 6 to 9 months; 3 = 9 to 12 months; 4 = 12 to 15 months.

[b] Slaughter weight group: 1 = 31.8 to 40.4 kg.; 2 = 40.5 to 49.5 kg.; 3 = 50.0 to 58.6 kg.; 4 = 58.9 to 67.7 kg.; 5 = 68.2 to 76.8 kg.

Table 8. Percent unacceptable overall palatability scores (scores 1 and 2) by roast type/age/gender/weight subclass.

Age group[a]	Slaughter weight group[b]	Shank				Butt			
		Ram	Ewe	Wether	All	Ram	Ewe	Wether	All
1	1	13.04	4.17	12.00	9.72	13.04	0.00	3.70	5.33
	2	7.14	12.50	3.85	7.69	7.14	0.00	4.00	4.00
	3	10.34	6.25	14.29	9.76	7.14	9.38	4.17	7.14
	4	7.69	4.35	9.52	7.14	8.33	0.00	0.00	3.03
	All	10.28	6.80	9.68	8.91	8.65	2.94	3.16	4.98
2	2	14.29	6.98	8.51	9.60	13.51	0.00	12.77	8.59
	3	9.30	0.00	2.13	3.91	5.00	2.56	2.04	3.13
	4	5.13	9.76	5.26	6.78	2.44	0.00	2.78	1.69
	5	3.03	3.03	9.09	5.05	8.33	5.88	2.94	5.77
	All	7.89	5.13	6.06	6.34	7.10	1.89	5.42	4.79
3	2	11.76	5.71	3.03	6.86	0.00	8.82	2.86	3.96
	3	9.76	2.56	2.44	4.96	16.28	2.56	7.14	8.87
	4	2.44	0.00	12.12	4.46	7.69	0.00	9.38	5.61
	5	3.03	6.06	2.94	4.00	3.23	9.68	0.00	4.17
	All	6.62	3.45	4.93	5.02	7.48	5.00	4.90	5.81
4	3	16.13	3.23	5.88	8.33	6.25	0.00	11.76	6.19
	4	3.03	11.43	0.00	4.90	5.88	8.82	8.82	7.84
	5	6.45	11.11	11.36	9.91	5.71	5.56	6.98	6.14
	All	8.33	9.52	6.19	7.96	5.88	4.81	8.93	6.60
All	1	11.11	7.69	11.54	10.13	11.54	0.00	3.70	5.00
	2	11.22	7.69	5.61	8.09	7.14	2.94	7.41	5.84
	3	11.11	2.86	4.90	6.32	9.09	3.55	6.04	6.24
	4	4.32	6.57	6.35	5.72	5.80	2.24	5.79	4.58
	5	5.10	6.86	8.11	6.75	5.83	6.93	3.60	5.40
	All	8.10	5.89	6.43	6.81	7.28	3.56	5.62	5.49

[a] Age group: 1 = 3 to 6 months; 2 = 6 to 9 months; 3 = 9 to 12 months; 4 = 12 to 15 months.

[b] Slaughter weight group: 1 = 31.8 to 40.4 kg.; 2 = 40.5 to 49.5 kg.; 3 = 50.0 to 58.6 kg.; 4 = 58.9 to 67.7 kg.; 5 = 68.2 to 76.8 kg.

A Review of the Nutritional Efficiency of Fiber Production in Goats and Sheep and the Relationship of Fiber and Meat Production[1,2]

Maurice Shelton[3]

Summary

A knowledge of nutrient requirements or nutritional efficiency of animal fiber production is important in decision making within the sheep and goat industries. Major differences in the level of fiber production exist within these species and this suggests some indecision on this point. Research on the efficiency of fiber production is very limited. This paper attempts to address this subject using a number of approaches. The results suggest marginal or partial efficiencies of use of metabolizable energy for fiber synthesis (6 to 19%) is much higher than that indicated by many earlier reports utilizing a simple ratio of feed consumed to fiber produced. On the other hand, the above stated range of values tend to be lower than those used in modeling studies or in the preparation of nutrient requirement tables. There is a very strong indication of a negative relationship between fiber and meat production under conditions where nutrition is a limiting factor throughout much of the production cycle. This is much less evident for animals maintained under good feed conditions. The end result is that producers may need to exercise control in attempting to increase the genetic potential for fiber production through selection or the introduction and use of the Australian Merino to flocks in the Southwest. If the increased fiber production comes at the expense of lamb production or requires a higher level of supplemental feeding, the result may not be favorable. In the final analysis, the decision may need to be based on type of feed resources and the relative value of lamb versus wool.

Key words: fiber production, sheep, goats, efficiency.

Introduction

A majority of the sheep in the United States, as well as throughout the world, produce merchandisable or useable fiber. However, the amount of wool produced varies from an extremely high level in sheep such as the Australian Merino to types such as tropical hair sheep which produce no merchandisable fiber. There are no sheep or goats which fail to produce fiber, but there are large differences in the amount or rate of fiber production and/or shedding. It is not clear to what extent reduced shedding is a contributing factor to fiber production or efficiency as fiber which is produced and shed would represent some expenditure of nutrients. Most of the variation in the level of fiber production is the result of natural or artificial selection. Several countries, including the U.S., have both extremes in respect to emphasis on fiber production in these species. Thus, there is clearly some indecision or disagreement among producers about the part that fiber should play in the present and future of the sheep and goat industries. It seems likely that fiber production has little or no place in humid tropical or subtropical regions. Some areas of the U.S. fit into this category, but much of the world's wool supply is produced in arid zones of temperate or subtropical regions.

Major differences exist in the inherent levels of fiber production among and within breeds and species. The level and quality of fiber produced are characteristics that are relatively easy to measure or observe and which respond well to selection. Information or insight into the nutritional efficiency of fiber production and the degree of competition between fiber and meat production appear necessary for intelligent decision making in determining

[1] Both sheep and Angora goats are treated in this discussion in the belief that the biological process and efficiency of fiber production is similar between the two species.

[2] The author would like to recognize the contributions of K. Qi for assisting in some of the calculations; and C.J. Lupton, Charles Parker, Hudson Glimp and T. Sahlu for reviewing the manuscript.

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the appropriate emphasis on fiber in production and selection programs.

Several authors have called attention to the apparent inefficiency of fiber production. MacFarlane and Howard (1972) state that "there is rarely 1% efficiency of energy use for wool production." Dolling and Piper (1968) reported that no more than 1.5% of the energy consumed appeared as energy in the form of wool fiber. A number of other reports state similar conclusions. Work with Angora goats (Gallagher and Shelton, 1972) indicated a lower feed-to-fiber ratio with this genotype, but the value is still only on the order of 2%. Numerous reports (largely from Australia) state that sheep selected for increased levels of fiber production produce fiber with improved efficiency relative to those with lower levels of fiber production (Hamilton and Langlands, 1969; Dolling and Moore, 1960; Dunlop et al., 1966). However, the authors quoted above are expressing overall efficiency, which has little relationship to true nutritional efficiency associated with fiber synthesis. When total feed intake is expressed as a function of increased fleece weight, the apparent increased efficiency of the more productive types merely represents a dilution of the maintenance requirement and may have little relationship to true efficiency of fiber synthesis. This gross efficiency has a close relationship with economic efficiency only in the case of wether animals maintained solely for fiber production. This has not been practiced to a significant degree with sheep in the U.S. for many years but continues to be practiced in other countries such as Australia. It has been widely practiced in the U.S. with Angora goats. In the wether animal fed at maintenance, energy consumed is used primarily for maintenance and fiber production. In this case, maintenance requires the major share of the nutrients, giving rise to the poor efficiency values quoted earlier. In the U.S. sheep industry, the breeding ewe is the basic producing unit. With this animal, the primary demands for nutrients in approximate order of priority are maintenance, growth, reproduction, lactation and wool growth. In this listing, wool production is shown as the last priority, but in practice the metabolic priority for fiber production depends on breeding. In animals such as the Angora goat and some types of Merino sheep, fiber production may be near the top in metabolic priority. In the latter case, some conflict in partitioning nutrients between fiber growth and other physiological functions (reproduction, lactation, growth) would be expected when nutrients are limiting.

The pertinent question, with respect to U.S. producers, pertains to the "true nutritional efficiency" of fiber production. In other words: "What is the nutrient cost of producing an additional unit of wool or mohair?" A clear cut answer to this question is difficult to formulate at present. No totally satisfactory procedure has been devised for partitioning the nutrients expended for fiber production from that utilized in other physiological processes. Wodzicka-Tomaszewska (1966), Butler and Maxwell (1984) and Reis and Sahlu (1994) have published review papers relating to efficiency of conversion of feed energy to fiber. Much of the discussion on the efficiency of fiber production derives from Merino selection experiments, as in the paper by Wodzicka-Tomasewska?? (1966) .

There are several physiological options to obtain increased wool production. One of these is larger-sized animals (e.g., Australian Strong Wool type) which almost certainly have a corresponding increase in feed intake (Schinkel, 1960; Ahmed et al., 1963). Another possible outcome of selection for wool production is that body weights or rates of growth are reduced, indicating that increased wool production comes at the expense of growth or size (Dolling and Moore, 1960). A third option is that efficiency of wool synthesis is improved. It is difficult to find good supporting documentation for the latter but Ahmed et al. (1963) suggest that 55% of the difference in wool production between strains in their study was due to improvements in efficiency and 45% due to increased feed intake. It is not clear how they arrived at this conclusion, or what types of efficiency they are talking about. Tomes et al. (1976) reported a negative correlation between body weight and efficiency of wool production in Merino rams, indicating some competition between these functions (Cronje and Smuts, 1994). Cronje and Smuts (1994) found no apparent differences in digestion or nutrient retention between groups with differing potential for fiber production, but the higher fiber producers partitioned a greater proportion of invested nutrients to fiber at a cost to other body tissue or functions. Also, some work indicates an increased metabolic rate associated with increased fiber production (Graham, 1968; Farrel et al., 1972) and this may well be at the expense of body weight or the efficiency or body weight gain or increased maintenance requirements (Ferguson, 1958).

At this point, it may be useful to attempt to define some of the terms used to express efficiency:

Gross Efficiency – Total feed energy intake divided by the amount of fiber produced. This value has little true relationship to the actual biological efficiency of fiber synthesis. A more appropriate expression of gross efficiency might also include an assessment for growth and reproduction as these functions are necessary (provide replacements) for an animal industry to persist or survive.

Net Efficiency – Butler and Maxwell (1984) define net efficiency as that measured at maintenance feed intake. This removes the complicating factor of tissue gain or loss and reproduction. This also has little relationship to the true efficiency of fiber synthesis as it includes maintenance costs charged to fiber growth, but would reflect the actual efficiency of wethers or females maintained only for fiber production.

Partial (Marginal) Efficiency – Used in this discussion in an attempt to express efficiency of fiber synthesis independent of other body functions. This is the true cost (efficiency) of fiber production in an animal such as the breeding ewe or doe in which maintenance, growth, etc., is changed to meat production.

Thus, partial efficiency is the value which should have a significant useful meaning to the U.S. producer, at least for developing breeding strategies for a dual- or multi-purpose animal. In the past, the Angora goat has been maintained primarily for fiber production. In this case, net efficiency may be a more realistic value for use in planning production or breeding strategies. In the future, it may prove necessary to treat the Angora goat as a dual-purpose animal, in which case partial or marginal efficiency becomes more important. Several approaches can be suggested to attempt to arrive at estimates of partial (marginal) efficiencies.

Methods of Estimating Nutritional Efficiency of Fiber Synthesis

Rattray et al. (1973a,b; 1974) estimated the efficiency of energy use by lambs employing multiple regression and found that the inclusion or deletion of wool energy did not significantly influence the slope of the regression line. This implies that the efficiency of energy use for wool synthesis did not differ from the mean for other body functions or that the quantity of wool produced, or the quantity of energy expenditure for wool production, was not sufficient to alter the coefficient. In these studies, the efficiency of utilization of metabolizable energy was on the order of 12.3% with wool included. If this value has meaning, it certainly differs from the 1.0 to 1.5% quoted earlier for gross efficiency.

The author has made repeated attempts (Shelton et al., 1976) to estimate the partial efficiency of energy use for fiber production by solving multiple regression equations. These studies used the individual animal data from the Rattray et al. (1973a,b) studies and sire group means from the ram test programs conducted at Texas Agricultural Experiment Station in Sonora, TX. Direct ratio estimates (gross efficiency) did not differ greatly from those quoted earlier. However, in these studies multiple regression procedures provided unrealistically high values for efficiency of fiber synthesis. This erratic result was thought to be to a statistical problem derived from the high (or significant) correlation between some of the variables included in the analysis (weight, maintenance, body weight gain, fiber produced, shrinkage loss). This experience tends to bring into question values reported in other studies that were derived using multiple regression analysis. However, a possible alternative explanation is that in animals fed for a high rate of body weight gain (above 0.6 pounds per day in the performance test program), the total energy expended for wool production is in fact generated from metabolites which the animal is unable to utilize for body weight gains. Supporting this possible explanation is the observation that a higher level of wool production does not markedly influence feed lot gains or efficiency in market lambs fed high-energy rations (Willingham et al., 1992). It may be worth noting that in the studies reported by Shelton et al. (1976) the energetic efficiency of weight gains were 24.4% for DE and 29.8% for ME, which is in the range of that reported by other workers for protein deposition.

Graham and Searle (1982) reported marginal (partial) efficiency of wool production was 16 to 19%. Quoting these same authors, Blackburn et al. (1987) used an efficiency figure of 20% in the construction of the Texas A&M Sheep Production Simulation Model. The method employed by Graham and Searle is not clear, but is being included in this discussion in the belief that multiple regression was employed to obtain the estimates.

Utilizing multiple regression procedures Herselman and Smith (1991) estimated the energy required for mohair production at 134.9 kJ/g (32.3 Kcal ME) which was stated to be approximately three times higher (greater cost) than the National Research Council (NRC, 1981) values for goats which were apparently calculated at 33% efficiency. The author's attempts to recalculate the values from this study yield estimates of approximately 2x rather than 3x of the values used in NRC (1981). A part of this difference may be explained by use of grease weight versus clean weight values for mohair production. Attempting to convert the above values to energetic efficiency yielded estimates of 15.3% DE and 18.6% ME utilizing 6,000 calories per gram of clean fiber.

Thus, we have efficiency estimates (mostly obtained from multiple regression) ranging from 12.3 to 19% with a value of 20% used in calculation of the sheep and goat model and 33% used in NRC calculations. It is the author's thesis that some of these values (20%, 33%) are overestimates of actual efficiency of fiber production. Perhaps more serious, the NRC Nutrient Requirements Tables for sheep make no provision at all for nutrients expended for wool production.

Another approach to calculation of efficiency would be through comparison of individuals or groups of individuals with different levels of fiber production and on which feed intake data are available. Any difference in energy intake could then be theoretically related to differences in fiber production. If the animals involved happen to be comparable in other respects, this procedure would appear to have value. Numerous Australian workers have reported studies on efficiency of wool production utilizing strains of Australian Merino which have been selected for higher or lower wool production or strains which naturally vary in level of wool production (Hamilton and Langlands, 1969; Dunlop et al., 1960, 1966; and others). Almost invariably, increased wool production is associated with increased feed intake. Thus, the ratio of differences in feed intake and fiber production can be construed as being related to the nutrient costs (partial nutritional efficiency) of fiber production. Fortunately, these strains tend to be somewhat comparable in size, metabolic rate (Graham, 1968) and digestive ability (Piper and Dolling, 1969). The author has identified eleven such comparisons from the literature. In ten of these comparisons, the higher wool-producing strain consumed more feed. This relationship is almost certainly real, but it is not entirely clear which is the cause and which is the effect. Body weight gains during the experimental period were essentially the same (0.1 kg), favoring the selected lines or high producing strains. In seven of the eleven comparisons, the higher wool-producing lines or strains were heavier. In the case of selected lines (Hamilton and Langlands, 1969) the lower wool-producing lines tended to be heavier, but in the strain comparisons the higher fiber-producing lines (Australian Strong and Medium lines) tended to be heavier and produce more and coarser wool and to consume more feed. In looking at selection lines (Hamilton and Langland, 1969), 7.09 Mcal of metabolizable energy were expended to produce 1 Mcal of energy in the form of wool (14.1% efficiency). Similar calculations made from strain comparisons yielded lower estimates of efficiency (7.73 and 6.94%) and may possibly be explained by differences in size. These values were obtained from wethers or unmated (non-pregnant, non-lactating) females maintained as nearly as possible at maintenance and are lower than those reported earlier by Graham and Searle (1982). A similar approach might be undertaken between breeds but this often involves large differences in body weight and body composition and the possible errors associated with attempting to correct for these differences.

Another possible approach to estimate the partial (marginal) efficiency of fiber production is to stimulate increased fiber production by use of protected sulfur-containing amino acids and to attempt to relate this increased production to increased feed intake. Two such experiments with Angora goats were reviewed (Bassett et al., 1981; McGregor and Hodge, 1989). In the McGregor and Hodge study (1989), ME was apparently used at 13.45% efficiency for fiber production whereas the application of this method to the Bassett et al. study yielded an estimate of efficiency of only 6.18%.

A fourth possible approach to estimating partial nutritional efficiency is to remove the maintenance component by calculation (using NRC values) where data are reported for body weight, feed intake and fiber production. When this approach was applied to the data on goats reported by Herselman and Smith (1991) the calculated efficiency of use of ME for fiber production was only 8.4%.

The prior discussion appears to strongly indicate that the values for efficiency of fiber production used in the preparation of the goat NRC publication (1981) and the sheep and goat model (Blackburn et al., 1987) are overestimated. However, the partial or true efficiency of feed use for fiber synthesis is considerably higher than the 1 to 2% values obtained by a simple ratio of feed intake-to-fiber produced. There is also some indication that the nutrient cost directly associated with fiber synthesis is much less for well nourished animals or animals on a high level of feed intake. This can have important implications for animal breeding or animal production schemes. All the estimates of efficiency discussed earlier, and shown in Table 1, are based on animals at or near maintenance. Attempts to calculate similar values for animals on a high level of feed intake or multiple levels of maintenance yield unbelievably high values. It seems likely that if optimum nutritional resources (amino acids and more especially sulfur-containing amino acids) are available at the tissue level where fiber synthesis is occurring, the efficiency of fiber synthesis may be greater and perhaps comparable to the synthesis of other proteins. No data were located where below-maintenance levels of feeding were practiced and which could be used to estimate efficiency.

The Relationship of Number of Lambs Born or Raised and Wool Production

Another way to look at the competition between lamb and wool production is to compare the wool produced by ewes raising 0, 1, 2 or more lambs. The literature reporting such data is extensive, but often too incomplete to provide a basis for calculations regarding efficiency. From the outset, it can be accepted that producing one or more lambs or kids reduces the amount of fiber produced within a given year or shearing period. In some more extreme cases, this may also carry forward to subsequent years. For instance, Beetson and Lewer (1985) reported that the production of a single lamb reduced fleece production by 8.3% and that rearing two reduced it by 16.6%. Gjdrem (1966) found that pregnancy and lactation reduced fleece weight by 11.2% while pregnancy alone reduced fleece weight by 4.3%. Similar values have been reported for Angora goats (Jones et al., 1935) in which fertility reduced fleece weights from 7 to 19% with grease fleece weights being more seriously effected than clean weights. Depending on shearing dates, the

Table 1. Some estimates of partial nutritional efficiency of fiber production as calculated from the literature.

Species	ME	DE	Reference
Multiple regression:			
Sheep	12.3	10.03	Rattray et al., 1973a, b
Goats	18.6	15.30	Herselman and Smith, 1991
Sheep	16.0	13.05	Graham and Searle, 1982
Sheep	19.0	15.50	Graham and Searle, 1982
By difference (genetic):			
Sheep	17.28	14.10	Hamilton and Langlands, 1969
Sheep	7.73	6.31	Dunlop et al., 1960.
Sheep	6.94	5.66	Dunlop et al., 1966
By difference (nutritional):			
Goats	13.45	10.98	McGregor and Hodge, 1989
Goats	6.18	5.04	Bassett et al., 1981
By calculation (removal of maintenance):			
Goats	8.38	6.84	Herselman and Smith, 1991

effect of pregnancy and lactation may be split between two shearing periods. Also, the nutritional conflict between these functions (gestation and lactation) and wool production is, no doubt, much greater than that reported by some authors, since these functions last only for a small part of the twelve-month shearing period. The more critical question is the reverse of this: "What is the effect of a higher level of fiber production on total lamb production?" In contrasting breeds, the high fiber-producing types such as Australian Merino and Angora goats tend to have lower reproductive and growth rates, at least when nutrition is limiting.

Pregnancy presents serious nutrient demands only for approximately 30 to 45 days in late gestation and the nutrient demands for lactation are concentrated in the first two to three months following parturition. The conflict between these two functions and fiber production may depend on the breed or genotype of animal involved (level of fertility, level of lactation, genetic potential or metabolic priority for fiber production) and the nutritional conditions involved. A part of the difficulty in making calculations from these types of data is that twin-bearing or -rearing ewes eat more feed, produce more milk, lose more weight and produce more lamb weight than open or single-rearing ewes (Gardner and Hogue, 1964; Snowder and Glimp, 1991). Lactation represents the greater nutrient demand and even for high fiber-producing types such as Angora goats may take precedence over fiber production (Sahlu et al., 1992). Thus, the conclusion that there is some conflict in the nutrient demands for these functions is inescapable.

Correlations (Weight, Reproduction and Fleece)

Another approach to looking at the relationship between traits or production functions is that of phenotypic or genotypic correlations. A phenotypic correlation is measured directly; it is the relationship between traits and measures on an individual animal and is a composite of genetic and environmental influences. Genetic correlations can only be calculated in an indirect manner by comparing traits or measures on related animals. As a result, genetic correlations are more erratic and difficult to interpret. However, it is – or should be – only the genetic correlations that hold interest for animal breeding. The environmental component of phenotypic correlations is often the major component and can contribute a significant element of confusion or lead to erroneous conclusions by the producer segment in formulating breeding policies. The major significance of the environmental influences is that the effectiveness of selection is improved if adjustments or corrections can be made for these influences.

Phenotypic correlations among performance traits (weight, growth, reproduction, fiber production) are nearly always positive. These correlations may range from near zero to highly significant values. Positive relationships between these traits would be expected, since environmental influences are a major factor and influence the above traits in a positive manner.

There is disagreement among values found in the literature in respect to the genetic correlation between fiber and meat production (lamb weight weaned). These values range from negative (Shelton and Menzies, 1968; Eikje, 1975; Kennedy, 1967; Snowder and Shelton, 1988) to significant positive values (Young et al., 1963; Basuthakur et al., 1973). Fogarty (1984) stated that "genetic correlations between reproduction and wool production are variable in size and magnitude, but tend to be small and negative." One of the more recent studies on this subject was that of Cloete and Heydenrych (1987). Their work suggests that there is little overall relationship of fleece weight and number of ewes lambing, but there is a tendency for low or negative relationships at a young age, becoming positive at maturity. However, lambs born of ewes mated tends to be negatively related to fleece production, with lambs raised of ewes mated becoming consistently negative (-0.46 and -0.32 for two data sets). They do not report data on number or weight of lambs weaned or total weight weaned, which might be expected to be even more adversely affected by a higher level of wool production. These results might be explainable in that among ewes with adequate development, the occurrence of estrus and ovulation represent limited demand for nutrients, whereas pregnancy and lactation represent a much greater nutrient outlay.

The author's interpretation of these data is that the relationship is greatly dependent on nutritional level or feed conditions. Where nutritional conditions are good, the proportion of the ingested nutrients which is expended on fiber production is small and may not represent direct competition except for very short times during the production cycle. Thus, any conflict in demands may not be measurable over the total production cycle. Any selection for overall productivity, including growth or reproduction, may favorably impact the animal through improvements or increases in size, fitness, viability or feed intake or utilization; thus, favorably impacting all aspects of production. By contrast, for animals in nutritional stress for a significant portion of their lifetime, there may be direct competition between wool production and body growth or reproduction. Support for this conclusion rests primarily from the significant negative genetic correlations (-0.25 and -0.29) reported by Shelton and Menzies (1968) and Snowder and Shelton (1988), respectively, for ewes grazing Texas ranges and the strong negative relationships reported by Kennedy (1967) for two-year-old Merino ewes under Australian range conditions. In the latter study, negative genetic correlations of -0.52 and -0.78 were reported between lambs born and grease and clean fleece weight, respectively, for yearling ewes. However, these same relationships became positive later in life. These differences may well have been even more marked if number or weight of lambs weaned had been reported. The study of Cloete and Heydenrych (1987) for Merinos in South Africa supports the above conclusions. Similar conclusions have been reported for Angora goats (Shelton, 1993).

Selection Experiments

The results of selection experiments support somewhat similar conclusions to those derived from correlation studies. Blair et al. (1984), working with Romney sheep in New Zealand, reported a good response to selection for fleece weight (using yearling fleece weight). Selected ewes became larger (thus presumably eating more feed) but there was no change in level of fertility. Barlow (1974) reported on selection experiments involving Merinos in Australia. He obtained a positive response to selection for fleece weight but reported that selected ewes raised significantly fewer lambs as two-year-olds (66.4 vs. 51.3% lambs raised). Lifetime lamb production also favored the low wool-producing strain, but the differences were less marked (81.4 vs. 76.8% lambs raised). Again, total weights of lambs weaned were not reported. Over their lifetime, ewes selected for high fleece weight had moderately higher lambing rates, but they also had a higher percentage of dry ewes and higher lamb mortality. In another study from New Zealand, Blair (1986) reported that selection for yearling fleece weight increased body size and reproductive performance. Young et al. (1963) reported that selection for fleece weight increased body weight (and thus presumably feed intake) but was not related to reproduction. More recently, Ercanbrack and Knight (1998) reported increased ewe body weights and a decline in fleece weight from selection for increased lamb production.

The results of selection experiments are preliminary and tend to suggest that there is some conflict between lamb and wool production (Barlow, 1974; Clarke, 1972). The conflict between lamb and wool production appears to be less under good conditions (e.g., Romney or New Zealand), but there is evidence of serious competition under less favorable nutritional conditions (e.g., Texas Rambouillet or Australian or South African Merino ewes under range conditions) and especially at a young age.

Protein and Wool Production

Animal fiber is essentially pure protein (keratin) and for this reason some must wonder why the focus on energy in this discussion. This is due to the fact that, quantitatively, the major nutrient requirement for fiber synthesis is energy. According to Dusenbury (1963), wool contains the following elements: carbon (50%), oxygen (22 to 25%), nitrogen (16 to 17%), hydrogen (7%) and sulfur (3 to 4%). Fiber consists mostly of polypeptide chains. Nitrogen occurs mainly in the form of the amide group in keratin from the 19 to 25 condensed amino acids. Animal fiber growth, under production conditions and among animals selected for fiber production, may run as high as 20 grams per day (7.3 kg per year). However, most breeds of sheep and goats produce significantly less. At the higher rate of production, 3.4 grams of nitrogen may be deposited as wool per day. Many good quality forages contain an adequate level of protein to support fiber production equivalent to the animals genetic potential. However, the protein needs for fiber synthesis is a much more complex issue than nitrogen requirements alone. What the animal actually requires at the tissue level are specific amounts of essential amino acids in an optimal ratio. The cells that synthesize fiber require relatively large amounts of amino acids containing sulfur. Wool contains 3 to 4% sulfur which is much greater than that of other tissue. The primary sulfur-containing amino acid found in wool is cystine. Some of the cystine in wool is formed in vivo utilizing methionine, another sulfur-containing amino acid, but the animal cannot synthesize methionine. Thus, both are essential, but they are not totally dietary essentials as the microbes in the rumen can synthesize the sulfur-amino acids to a limited extent. The protein available to the ruminant animal for fiber synthesis is not the dietary protein, but is made up largely of microbial protein exiting the rumen. This microbial protein may be adequate in quality or quantity to support most body functions in the ruminant, but it is well recognized that a deficiency of sulfur-amino acids at the tissue level is often the first limiting nutrient for fiber synthesis. This deficiency is much greater for the high-producing strains (Calhoun et al., 1981). To some degree this apparent impasse is or can be circumvented by the concept of by-pass protein, which passes through the rumen without being degraded and becomes available as dietary protein in the lower tract. Protein loading (a high-protein diet) contributes to by-pass protein through physical by-pass before digestion is complete or before deamination has occurred (Dror and Bondi, 1969). Also, ensuring an adequate level of sulfur in the diet permits maximum synthesis of sulfur-amino acids. Qi et al. (1992) suggest that the optimum nitrogen to sulfur ratio for a high fiber-producing type (the Angora goat) is on the order of 7.2:1 as contrasted to 10:1 used in the NRC for goats and 15:1 considered adequate for animal nutrition in general.

As shown in Table 2, protein level does have a major impact on body growth and wool production and there is a differential response between the two outputs with respect to protein level and genetic potential for fiber synthesis (Piper and Dolling, 1969). These data support several observations. One of these is that animals with a high genetic potential for fiber production are prevented from expressing this potential at low levels of protein intake. At very low levels of protein (6.9% crude protein in the above study), feed intake, growth rate and fiber production are seriously impaired and differ little between animals of different genetic potential. At a high crude protein level (17.8%) versus a moderate level (13.6%), fiber production increases in the high-potential animal to a higher level than the low-potential animal. The fleece production of the high-potential animal appears (in this case) to be at the expense of the body weight gains. In this case 9.4 pounds less body weight was associated with 740 g (1.63 pounds) of clean wool. Alternatively stated, 5.7 pounds less body weight is associated with each pound extra of clean fleece. This could be very critical in young breeding ewes or does. It has also been shown that Angora goats respond in a similar manner to higher protein intakes (Huston and Shelton, 1967).

Wool Wax and Wool Production

Another unknown concerning the nutrient cost of wool or fiber production is the energy required for synthesis of wool wax. Wool wax is the term used to refer to the secretion of the sebaceous glands associated with the wool follicle. After recovery from the scouring fluid, it is often referred to as wool grease, and when it has been further refined it is known as lanolin. It is not a "fat" because it does not normally contain triglycerides. It is essentially a mixture of high molecular weight esters formed from several sterols, aliphatic alcohols and diols combined with straight and branched chain and hydroxy fatty acids. Although purified lanolin has a great diversity of uses, the sheep producer does not normally realize any direct compensation for this product. The yield of the fleece varies inversely with the wax content, but other factors such as density of the fleece, suint production, dirt content and production conditions in general may influence yield as well. Aside from fleeces obtained under wet or muddy conditions, the yield of wools range from 35 to as high as 80%, with finewools tending to have lower values. The yield of mohair generally ranges from 65 to 85%, with dirt and vegetable defect providing much of the loss. The wax content of the fleece (of wool) seldom makes up more than 15% of the weight, but its effect on yield may be much greater due to its tendency to bind with dust, dirt or other foreign materials.

Wool wax or grease can be burned as a fuel and contains 40 MJ/kg (9.57 Mcal/kg). The term "suint" refers to the water-soluble portion of the scouring loss from the fleece. This material derives from the sudoriferous or sweat glands associated with the follicles. Suint is thought to be potassium salts of fatty acids ranging from valeric to palmitic. Suint content generally ranges from 10 to 13% of the weight of greasy wool (Dusenbury, 1963). The secretion of suint is derived from the primary follicle, which would not be uniquely related to producing wool and mohair and thus might be a part of maintenance. Wool wax is more uniquely derived from the sebaceous glands which tend to be associated with secondary follicles and this would be related to increased fiber production. No studies have been identified by the author which address the nutritional cost or nutritional efficiency of synthesis of wool wax or grease, but circumstantial evidence suggests that the nutrient cost of producing wool wax may equal or exceed that of the synthesis of fiber. The first such indication is that high oil-producing types of Merino sheep and Angora goats tend to be smaller, less robust and have lower levels of reproduction than high-yielding types. At one time in their history, both genotypes were selected for a high oil content to increase grease fleece weight. Another source of evidence of a high nutrient cost of synthesis of wool grease is that multiple correlation studies (Shelton et al., 1976; Snowder, 1985) have shown an equal or larger coefficient associated with shrinkage loss (a function of wax or grease content) than with clean fibers present. One thing this tells us is that since producers do not normally receive payment for oil content of the fleece they would be advised to exercise a preference for higher-yielding types, especially if the clip is to be merchandised on the basis of clean yield. Some Australian Merino types yield as high as 75% compared to 50 to 55% for most Rambouillets. It is not known (at least to the author) to what extent this difference is due to a lower oil content or a greater density which reduces dirt penetration. If it is assumed that wool grease makes up 12.5% of the total weight of the fleece yielding 50%, then wool grease would represent 25% of the weight of clean fiber present. Thus, the nutritional cost calculations for wool have been increased 25% to partially account for this. This is very empirical, but the author suggests that the true cost may in fact be greater. No such correction has been made in the case of mohair due to the fact that the oil content of mohair is much lower (less than 3%). However, in calculations involving efficiency the maintenance requirements of goats have been increased by 25% to account for their activity on the range as suggested by the NRC for goats (1981).

Discussion

It seems obvious that the nutrient requirements for fiber production should be considered in designing nutrition and breeding programs and

Table 2. The relationship of protein level and genetic potential for fiber production on feed intake, growth and production (140-day period).[a,b]

	Clean wool, g (pounds)	Clean wool, g (pounds)	Final body weight, pounds (kg)		Gross energy intake, Mcal	
Crude protein level, % of ration	High potential	Low potential	High potential	Low potential	High potential	Low potential
17.8	1,908 (4.2)	1483 (3.3)	82.2 (37.4)	89.1 (40.5)	624	634
13.6	1,579 (3.5)	1,264 (2.8)	84.0 (39.3)	86.5 (39.3)	610	629
6.9	431 (0.95)	442 (0.97)	47.1 (21.4)	48.2 (21.9)	221	213

[a] Adapted from Piper and Dolling (1969).

[b] Merino sheep were fed ad libitum isocaloric rations, differing only in protein content.

that any subsequent revision of the NRC for sheep should include an allowance for nutrients expended for this purpose. Utilizing some of the information presented in the previous discussion and energy requirements from NRC Tables, it is possible to estimate the feed required for fiber production. Interested parties are encouraged to make their own calculations as the end results are greatly influenced by genotypes involved and assumptions relating to production components. In the author's attempts to make such calculations, the amount of good quality feed required to produce one pound of fiber utilizing partial or marginal efficiency values was estimated to range from 25 to 30 pounds. Similar values based on net efficiency (including a charge for maintenance) would be approximately 150 to 200 pounds; values for gross efficiency (including growth and reproduction or replacements) ranged as high as 400 pounds. The lower values were derived from or apply to animals with a high genetic potential for fiber production such as Angora goat and Merino sheep while the higher values apply to Rambouillet ewes. The difference between these estimates represent not only a higher genetic potential and metabolic priority for fiber production, but a lower requirement for maintenance and lower expected levels of growth and reproduction.

Since Angora goats are kept primarily for fiber production, the net efficiency figures are more applicable with the result that production costs (feed costs alone) almost certainly exceed the current market price for mohair. Thus, not surprisingly, their numbers have crashed in the years since the termination of the incentive program for mohair. A similar situation might apply to Merino sheep (especially wethers) kept primarily for wool production. This industry has not existed in the U.S. for several decades and is declining in other countries such as Australia.

A more critical question is the place of wool in the current and future U.S. sheep industry. Using partial or marginal efficiency figures (e.g., charging all maintenance, growth and reproduction to meat production) a modest price (as at present: July, 1998) can cover feed costs if forage quantity and quality is adequate to produce wool and at the same time support a high level of lamb production. If the contrast is wool (fiber) versus no wool, producers may wish to add a cost for shearing and marketing. On the other hand, if it is necessary to introduce more expensive harvested grains or supplemental feed to provide an adequate level of nutrition or that wool production comes at the expense of lamb production, the results will likely be unfavorable at recent price levels. Evidence that increased wool production may come at the expense of lamb production (see Cronje and Smuts, 1994) on Texas ranges may be seen from the reports of Willingham et al. (1994a,b) following attempts to introduce the genetic potential for a higher level of wool production by introducing the Australian Merino. This trend was less evident at some other locations (Snowder et al., 1997). Under present conditions it may be more advisable to suggest that in lieu of increasing the level of wool production under harsh feed conditions, producers might be encouraged to concentrate their efforts on improved marketing and improving the quality traits of wool such as color, length and fiber diameter. Also, it would appear that there may be a place or a potential for non-wool-producing breeds of sheep if they have other desirable traits such as fitness, a high reproductive rate and produce lambs with desirable carcass traits.

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Research Briefs

Nutrient Partitioning in Merino Rams with Different Wool Growth Rates

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A total of 45 Merino rams from a selection flock were used in this experiment. The rams were classified as high, medium or low wool producers based on a preliminary period (18 months to 2 years) at pasture. The animals were subsequently fed a basal ration at maintenance and ad libitum. Nutrient intake was partitioned into feces, urine, body and wool. The respective values of the ad libitum fed group were 0.30, 0.41, 0.24 and 0.05 for nitrogen (N) and 0.31, 0.03, 0.646 and 0.015 for energy. The nutrient intake did not differ significantly between the groups with differing wool production potential. The level of wool production during the experimental periods was highly correlated with that during the preliminary period and the differences in level of fiber production was much greater in the ad libitum fed group. There were no apparent differences in digestion or nutrient retention between the genetic groups, but the high wool producers partitioned a greater proportion of both N and energy to wool production than the low wool producers. If increased nutrient partitioning towards wool production occurs at the expense of other body tissue, then reproduction, growth rate and fitness may be reduced. However, this may not be apparent under conditions of nutrient excess. The authors conclude: "Merino rams of high clean-wool production potential are not more efficient, but partition more of the available nutrients to wool production at the cost of other body tissue deposition."

Prepared by Maurice Shelton.

News & Notes

The *Sheep & Goat Research Journal* has a New Publisher

With this release of the last issue of Volume 14, the American Sheep Industry Association (ASI) will cease to be the publisher of the *Sheep & Goat Research Journal*. Starting with Volume 15, this responsibility will be taken over by the Livestock Conservation Institute (LCI), a non-profit organization which has been in existence for over 80 years and has been concerned largely with animal health and well-being. With this initiative, LCI plans to broaden their interest to include additional programs and services.

Communications concerning subscriptions, policy, etc., should be addressed to LCI. Manuscripts (five copies) should also be submitted to the following address:

Livestock Conservation Inst.
1910 Lyda Drive
Bowling Green, KY 42104-5809

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Dr. Maurice Shelton will continue to serve as Editor through the completion of Volume 15. You may communicate with him in matters pertaining to the *Sheep & Goat Research Journal* at the following address:

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The mission and purpose of the Journal will remain the same and ASI will continue to support LCI in this initiative in any way possible. Your support is requested and appreciated in the form of subscriptions, manuscripts, reviews, suggestions and support.

Sheep & Goat Research Journal
Guidelines for Authors

Objective

The aim of the Sheep & Goat Research Journal is to provide a publication of sheep and goat research findings which can be used by scientists, educators, Extension agents and sheep and goat producers alike. The specific goal of the Journal is to gather and distribute current research information on all phases of sheep and goat production and to encourage producer use of research which has practical application. The Journal is published three times each year.

Editorial Policy

We are most interested in publishing articles of research relating to all aspects of sheep and goat production and marketing. Articles should relate and contribute to the advancement of the American sheep and goat industries and/or their products. All research manuscripts must represent unpublished original research. The submission of review articles is encouraged but will require review as well as those reporting original research. Articles which promote commercial products or services will not be approved for publication. Conclusions reached must be supported by research results. An orientation to practical applied research which may be useful to the sheep and goat industries is encouraged. At least one author of each manuscript must subscribe to the Journal.

Review Process

Manuscripts will be subject to critical review by an editorial board or others designated by the editor. Authors will be notified of acceptance or rejection of papers by mail. Manuscripts needing revision will be returned to authors and should be revised and returned by the deadline indicated. When papers are accepted for publication, the authors must send a floppy disk with the manuscript in the ASCII file format along with two hard copies. Papers not suitable for publication will be returned to the authors with a statement of reasons for rejection. Consult the Sheep & Goat Research Journal Editorial Policy and Procedures for details of the technical requirements for manuscripts submitted to the Journal.

Guidelines

Several sources were consulted, including the Journal of Animal Science and the Council of Biology Editors, Inc., when preparing these guidelines. Though the nature of the Journal is such that relatively few regulations are needed on style and form, we have attempted to standardize the manner in which the material is published as a service to Journal subscribers. Following are general guidelines for style and form.

Format

Manuscripts must be typed and double-spaced; five copies must be submitted. The lines on all pages including those pages for Literature Cited and Figure Legends must be numbered in the left margin beginning with the numeral one (1) at the top of the page. Tables should be as few and as simple as is feasible for presentation of the essential data; tables should be typed and double-spaced. Each table should be on a separate sheet. All figures used in the text must be camera-ready. The author will be billed at full cost if figure preparation is required.

Research manuscripts should follow the format of:

1st	**Summary** (250 words or less)
2nd	**Key Words** (up to 6)
3rd	**Introduction**
4th	**Materials and Methods**
5th	**Results and Discussion**
6th	**Conclusions**
7th	**Literature Cited**

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