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Editor: Maurice Shelton

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Editorial Review Board

American Sheep Industry Association

6911 South Yosemite Street
Englewood, CO 80112-1414
Phone (303) 771-3500
Fax (303) 771-8200

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Limit-Grazing of Cool-Season Pastures for Wintering Angora Does[1,2]

Steve Hart[3,4] and Tilahun Sahlu[3]

Summary

Forty pregnant Angora does were wintered on *ad libitum* Bermudagrass hay with 20 does receiving one pound of a 16% concentrate supplement and the other 20 does allowed to graze a pasture mixture of wheat and ryegrass for two hours per day. The limit-grazed does consumed half the quantity of the hay as the supplemented does and consumed less dormant forage in their pastures. The supplemented does lost 6% of their body weight (BW) during the study, whereas the limit-grazed does maintained their weight. The limit-grazed does produced more clean fleece with no effect on staple length or fiber diameter. Limit-grazing of cool-season pastures improved animal performance while reducing hay and supplement requirements.

Key words: Angora goat, mohair, supplement, pasture.

Introduction

Shelton and Calhoun (1969) suggested that since the protein content of wheat pasture far exceeds the nutrient requirements for most classes of sheep and goats, intermittent grazing of cool-season pastures for a few hours per day or a few days per week could provide the necessary protein. They observed that grazing oat forage two days a week supported similar kid performance (2.0 pounds vs. 1.0 pound gain per 42-day period) to feeding 0.4 pounds of supplement per day. Similar results were obtained in their study with yearling ewes. Altom (1978) listed the benefits of limit-grazing as increased stocking rate and the ability to continue grazing during temporary forage shortages. Altom (1978) estimated that cattle grazing one hour per day consumed 2.2% of their BW, whereas those grazing two hours per day consumed 3.3% of their BW and stopped grazing. The objective of this study was to compare performance of pregnant Angora does wintered on hay and either protein supplement or limit-grazed on wheat pasture.

Materials and Methods

Four pastures with 10 pregnant Angora does (three- and four-year-olds) in each were used to evaluate two systems of overwintering Angora goats with two pastures per treatment. The study was initiated November 25, 1991, following initial shearing of goats; the study was terminated April 14, 1992, when the first doe kidded. Does were blocked by initial BW (10 blocks) and randomly assigned to pens. Pens were 1.03 acres of standing dormant forage (native tallgrass prairie). Each pen had hay feeders with keyhole feeder slots for feeding chopped bermudagrass hay. Each pen of goats was randomly assigned to treatments. One treatment was supplemented with one pound of a protein supplement per head per day and the other treatment was limit-grazed on a cool-season forage for two hours per day instead of the protein supplement. The protein supplement (formulated to contain 16% crude protein [CP] and 1.36 Mcal of metabolizable energy per pound of dry matter [DM]) was composed of 92.1% ground corn, 5.0% dried molasses, 2.0% urea and 0.9% calcium sulfate. Supplement was fed in early afternoon in eight-foot troughs. Orts (uneaten food) were collected daily. Limit-grazed goats were put out on cool-season pastures in early afternoon for two hours. The cool-season pastures were a mixture of Marshall ryegrass and wheat that had been planted at the rate of 100 pounds per acre in early September following application of fertilizer (100 pounds N and 45 pounds P per acre). Each of the wheat-ryegrass pastures were 4.6 acres. Hay was fed in the morning and orts were weighed daily. Pastures of dormant forage and the

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[3] E (Kika) de la Garza Institute for Goat Research, P.O. Box 730, Langston University, Langston, OK 73050.

[4] To whom reprint requests should be addressed.

cool-season pastures were sampled at three-week intervals by hand clipping three 1.5 square-foot quadrats. Forages were dried at 65 °C and ground for subsequent analysis of crude protein (Association of Official Analytical Chemists, 1984) and acid detergent fiber (Goering and Van Soest, 1970).

Goats were sheared at termination of the study, fleece weights were recorded and a fleece sample was obtained from the mid-side area during shearing. Fiber diameter (Peyer FDA 200 system, Wallerau, Switzerland), yield (American Society for Testing Materials, 1988) and staple length were determined. Ruminal fluid and venous blood samples were taken the morning of February 20, 1992. Prior to grazing or feeding in the afternoon, pens were sampled in a sequence to mitigate the effects of time. Ruminal fluid was analyzed for ammonia (Technicon Instruments, Tarrytown, NY) and volatile fatty acids (Ottenstein and Bartley, 1971). Plasma cortisol, insulin, triiodothyronine and thyroxine were analyzed using commercially-available kits (Cambridge Medical Diagnostics, Billerica, MA) as described previously by Sahlu et al. (1992). All samples were analyzed in one assay. Interassay coefficient of variation for insulin, cortisol, triiodothyronine and thyroxine were 6.2, 4.6, 5.3 and 5.5%, respectively. The experiment was analyzed statistically as a completely random design with pen as the experimental unit.

Results and Discussion

Does on the supplemented treatment consumed all of their supplement (Table 1). They also consumed more hay ($P < 0.001$) than limit-grazed goats. As standing forage was consumed, hay intake of the supplemented does increased from 0.1 pound per head per day in the first week to 0.9 pound per head per day by week four and continued at that level until the conclusion of the study. Hay intake followed a similar pattern for limit-grazed does consuming 0.05 pound per head per day in the first week and 0.5 pound per head per day at week four and following.

Limit-grazed does gained BW while those receiving the supplement lost weight during the wintering period ($P < 0.05$). This is consistent with findings by Shelton and Calhoun (1969). Limit-grazed does produced more greasy fleece which had a higher yield, resulting in more clean fleece ($P < 0.05$) than supplemented does. Fiber diameter was increased slightly by limit-grazing, whereas staple length was not affected by treatment ($P > 0.20$). Analysis of variance indicated that differences in staple length and diameter each accounted for only 10% of the variance in clean fiber production. This suggests that increased fiber production must have come from increased fiber follicle activity. This is consistent with our previous studies on the effect of improved nutrition on fiber yield (Sahlu et al., 1992; Hart et al., 1993). The only way that fiber follicle number could be increased would be if inactive fiber follicles were recruited to active follicles by improved nutrition. However, we are unaware of any published data that supports this hypothesis.

Plasma hormones were not affected by treatment except for glucagon which was lower ($P < 0.05$) for does that were limit-grazed (Table 2). This is consistent with the greater weight gains of these goats. Ruminal ammonia levels were similar for both treatments. The molar percent of isobutyric acid was greater for grazed goats, whereas the molar percent of butyrate was greater for supplemented goats. The greater molar percent of isobutyrate may relate to the high levels of soluble protein in wheat forage (Horn et al., 1977) which is readily degraded by ruminal bacteria since concentrations of valerate and isovalerate were also elevated, but not significantly. Acetate-to-propionate ratio was also increased on the supplemented group.

Dormant forage availability was greater for goats on the supplemented treatment at initiation of the study (5,130 vs. 4,240 pounds per acre) and was lower at the end of the study (810 vs. 1950 pounds per acre) indicating greater DM removal (17.4 vs. 34.0 pounds per day; $P < 0.05$) by supplemented goats (Table 3). It should be noted that in both treatments the DM disappearance is due not only to consumption, but also to trampling and weathering. Forage quality of the dormant grass was low, reflecting plant maturity and weathering. The wheat-ryegrass pasture initially had a low forage availability (1,400 pounds per acre) but increased to 5,540 pounds per acre by termination of the experiment. The wheat-ryegrass mixture grew very rapidly after the winter dormancy period. Forage availability did not limit intake and the quality of wheat forage was very high (mean CP = 17.2%) throughout the grazing season.

Table 1. Intake, bodyweight gain and fleece characteristics of goats limit-grazed or offered a protein supplement.

Item	Limit-grazed	Supplement	SE[a]	Significance P <[b]
Supplement, lb/day	–	1.0	–	–
Hay intake, lb/day	0.48	0.89	0.03	0.001
Initial weight, lb	66.7	67.2	0.44	NS[c]
Final weight, lb	67.3	63.0	1.8	0.05
Gain, lb/day	0.01	-0.07	0.03	0.05
Grease fleece weight, lb	5.43	4.15	0.70	0.10
Clean yield, %	79.3	75.6	2.4	0.05
Clean fleece, lb	4.29	3.17	0.44	0.05
Staple length, cm	9.40	9.73	2.56	NS[c]
Fiber diameter, m	36.5	34.8	1.4	NS[c]
Ratio[d]	2,589	2,808	250	NS[c]

[a] SE = standard error of the mean.
[b] Probability of treatment difference.
[c] Not significant (NS) = P > 0.10.
[d] Ratio of length divided by fiber diameter.

Cortisol was numerically lower for the limit-grazed treatment. This is consistent with observations of Sahlu and Fernandez (1992) of lower cortisol levels with nutritional improvements which increased mohair production. This is consistent with observations by Chapman and Bassett (1970) that administration of cortisol reduced wool production.

Conclusions

Limit-grazing does only two hours a day improved weight gains and fleece production while reducing hay requirements as compared to goats given a protein supplement. Unfortunately, we were not able to measure forage intake or estimate to what extent carrying capacity of the cool-season pasture was increased. However, this research demonstrates the high value of cool-season pasture even in limited quantities. It also shows that when a cool-season forage is in limited supply, limit-grazing can still improve animal performance while extending the forage supply. The results of this study indicate potential for grazing less than two hours per day or even on alternate days to extend forage supply even further.

In addition, limit-grazing would be expected to reduce trampling damage to the forage and thereby increase forage production.

Table 2. Plasma and ruminal fluid constituents of goats limit-grazed or offered a protein supplement.

Item	Limit-grazed	Supplement	SE[a]	Significance P <[b]
Thyroxine, µg/dl	8.55	9.30	0.70	NS[c]
Triiodothyronine, ng/dl	235.0	261.0	29.0	NS[c]
Cortisol, ng/ml	3.34	3.60	0.60	NS[c]
Insulin, µU/ml	18.3	17.4	1.8	NS[c]
Glucagon, pg/ml	376.0	489.0	28.0	0.05
Rumen ammonia mg/dl	6.5	8.9	3.7	NS[c]
VFA, Molar %				
Acetic (A)	66.8	67.6	2.1	NS[c]
Propionic (P)	21.5	18.7	2.23	NS[c]
Isobutyric	1.69	0.79	0.44	0.05
Butyric	8.1	11.4	2.4	0.10
Isovaleric	1.01	0.85	0.38	NS[c]
Valerate	0.86	0.61	0.24	NS[c]
A:P	3.17	3.72	0.31	0.10
Total concentration, mM	40.7	70.6	17.	0.10

[a] SE = standard error of the mean.
[b] Probability of treatment difference.
[c] Not significant (NS) = $P > 0.10$.

Table 3. Average forage availability and chemical composition during the grazing period.[a]

Pasture	Average standing forage, pounds per acre	CP[b], %	ADF[c], %
Dormant forage in pen:			
Supplemented	3,418	4.19	47.8
Limit-grazed	3,504	3.76	48.6
Wheat-ryegrass pasture	3,103	17.2	24.8

[a] Mean of seven sampling periods at three-week intervals, two pastures with three samples per pasture in each sampling period.
[b] CP = crude protein.
[c] ADF = acid detergent fiber.

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Implications of U.S.-Mexico Tariff Reductions under NAFTA for the U.S. Sheep Industry[1]

Everett B. Peterson[2] and Rodney Jones[3]

Summary

Under the North American Free Trade Agreement (NAFTA), Mexico will eliminate its tariffs on United States' exports of live sheep and mutton and lamb over a 10-year period, while the U.S. will eliminate its tariff on Mexican mutton and lamb products immediately. The effects on the U.S. sheep industry from removal of these tariffs are shown to be quite modest. Our model results indicate that with greater access to the Mexican market, U.S. live sheep exports to Mexico increase by 13.7%. However, because the Mexican live sheep market is smaller than the U.S. live sheep market, total U.S. sheep production increases by only 0.9%. This increase in export demand leads to a 1.6% increase in the U.S. live sheep price.

Keywords: NAFTA, tariff reductions, sheep.

Introduction

By ratifying the North American Free Trade Agreement (NAFTA), the United States, Mexico and Canada are in the process of forming a large free-trade area. In general, all three countries are to replace non-tariff barriers, such as quotas, with tariffs and then to gradually eliminate all tariffs over a specified time period. For processed lamb and mutton products, the United States will eliminate its tariffs on Mexican products immediately, while Mexico will eliminate its tariffs over a 10-year period. For live sheep, Mexico will again phase out its tariffs on U.S. exports over a 10-year period, while the United States has no existing tariffs on Mexican live sheep imports.[4] Even though Canada has also agreed to eliminate trade restrictions, trade in live sheep and processed mutton and lamb products is virtually nonexistent between Canada and the U.S. and Mexico. Thus the Canadian market, with its relatively small sheep industry and minimal consumption of lamb and mutton, will not be a major factor in determining the impacts of NAFTA on the U.S. sheep industry.

During the debate on NAFTA, the American Sheep Industry Association (ASI) supported the ratification of the agreement. Because Mexico is the largest single export market for U.S. sheep and lamb products, ASI viewed the reduction in Mexican tariffs as an opportunity to increase U.S. exports. Also, because U.S. imports of Mexican live sheep and processed mutton and lamb have been historically very small (30,000 pounds in 1991), ASI did not perceive much of a threat from increased mutton and lamb imports from Mexico. However, like other commodity groups, ASI was concerned about strict enforcement of the Country of Origin rules in NAFTA. Without strict enforcement, transshipment of live animals and frozen mutton and lamb products through Mexico could occur. Transshipment of woolen textiles imports through Mexico could also potentially lead to increased woolen textile imports to the U.S.[5]

Given the great deal of controversy generated by the NAFTA debate and the support of NAFTA by ASI, this paper assesses the potential effects of eliminating U.S. and Mexican tariffs

1 Helpful comments from Wayne Purcell and two anonymous reviewers are gratefully acknowledged.

2 Assistant professor, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0401.

3 National Needs Marketing Fellow, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0401.

4 Imports of breeding stock to Mexico currently have no existing tariff.

5 Because NAFTA does not require the U.S., Mexico and Canada to harmonize their respective trade policies, Country of Origin rules have been included to provide safeguards against product transshipment, transformation and other means of circumventing established market access by non-NAFTA countries. The transshipment of live animals may also pose an animal health threat.

on live sheep and processed mutton and lamb on the U.S. price and production of live sheep, raw wool and mutton and lamb. While previous research (Grennes and Krissoff, 1993; Melton and Huffman, 1993; and Rosson et al., 1993) has assessed the impacts of NAFTA on other livestock industries, particularly beef, none to our knowledge has focused on the U.S. sheep industry.

Attention is focused entirely on the removal of trade barriers for live sheep and mutton and lamb because of the relatively small wool industries in the U.S. and Mexico.[6] Both countries only produce a small fraction of the total raw wool demanded by textile mills in each country, and raw wool trade between the two countries is virtually nonexistent.[7] Given strict enforcement of the Country of Origin rules, reducing raw wool trade barriers between the U.S. and Mexico should not have significant impacts on the U.S. sheep industry.

Materials and Methods

To determine the impacts of reduced trade barriers for live sheep and lamb products under NAFTA, we employ an intermediate-run, comparative static partial equilibrium model focused on the sheep sector.[8] The model has three regions: U.S., Mexico and the rest of the world (ROW). Each region has two sectors: sheep and sheep processing. All markets are assumed to be perfectly competitive. Like most other partial equilibrium agricultural trade models (e.g., OECD, 1990; Roningen and Dixit, 1989; and Valdes and Zietz, 1980), transportation costs are not considered, given a lack of information and the aggregate nature of the analysis.

The sheep sector is assumed to produce both live sheep and raw wool. In the U.S. and Mexico, sheep producers may sell their live sheep to either U.S. or Mexican sheep processors, while ROW sheep producers may only sell their live sheep to ROW sheep processors. Thus we assume that only the U.S. and Mexico trade live sheep.[9] However, sheep producers in each region may sell their raw wool to either domestic or foreign textile mills. Based on trade data that indicate small two-way trade flows between the three regions, live sheep and raw wool are treated as homogenous commodities. For a homogenous commodity, one would expect a region either to import or export the commodity, ignoring spatial considerations. Thus there is a single world market for raw wool and a single U.S.-Mexico market for live sheep.

The sheep processing sector is defined as performing all slaughter, transportation and retailing activities in order to produce a retail processed mutton and lamb product. Sheep processors in each region may sell their product to both domestic and foreign consumers. Given observed two-way trade flows in processed mutton and lamb, the sheep processing sector in each region is assumed to produce a slightly different product. Therefore the price of mutton and lamb processed in the U.S. will differ from the price of mutton and lamb processed in Mexico or ROW.

Consumer Demand for Mutton and Lamb

Given the above broad overview of the model, we next turn to a description of consumer behavior in our model. We use a single representative consumer in each region to determine the demand for mutton and lamb products from an underlying preference structure and a budget constraint. In general, the demand for any good is a function of all other prices and the level of consumer income. However, to model demand in this manner is empirically impractical, so we invoke the widely used economic assumption of weakly separable preferences that allows us to focus on a smaller, more closely related subset of goods. In particular we focus on the consumer demand for meats: beef, pork, poultry and mutton and lamb.

We view the consumers in each region as employing a three-stage budgeting process. First, consumers decide how much of their budget to allocate to meat products, and then how much to allocate to beef, pork, poultry and mutton and lamb. Consumers will increase their total consumption of mutton and lamb as its price decreases, as the price of beef, pork, or poultry increases or as income increases. In the third stage, consumers allocate their total mutton and lamb expenditures on mutton and lamb products from each region, based on relative prices.[10]

To illustrate this preference structure, consider the behavior of the Mexican consumer following a reduction in the price of U.S. mutton and lamb from the elimination of Mexican tariffs, holding all other mutton and lamb prices constant. Because U.S. mutton and lamb is now relatively cheaper than Mexican or ROW mutton and lamb, Mexican consumers will substitute away from Mexican products and increase consumption of U.S. mutton and lamb. In addition, mutton and lamb are now relatively cheaper than other meats, so Mexican consumers will also increase their total consumption of mutton and lamb at the expense of other meats. Thus the demand for U.S. mutton and lamb receives a double boost. Also, the demand for Mexican and ROW mutton and lamb by the Mexican consumer could also increase in this example if there is a large enough increase in total mutton and lamb expenditures, reallocated from other

6 In 1991, the United Nations (FAO) estimated that the U.S. and Mexico combined produced approximately 45,000 metric tons of raw wool, or about 2.5% of total world production.

7 In 1991, U.S. production of raw wool supplied only about one-third of total U.S. textile mill demand for wool (U.S. Department of Agriculture, FATUS, July 1992).

8 The intermediate-run refers to a time period sufficient for all markets to reach their new equilibria, but not long enough for substantial changes to occur in production technologies, consumer preferences or other important exogenous factors.

9 There is a very small amount of live sheep imports to the U.S. and Mexico originating from third countries, mainly from Canada. Because of the historically low levels of imports into the U.S. and Mexico from third countries, we do not consider trade in live sheep between ROW and the U.S. and Mexico.

10 We use a Constant Elasticity of Substitution (CES) sub-utility function to represent consumer preferences at the third stage.

meats, to offset the higher relative prices of Mexican and ROW mutton and lamb (i.e., if the income effect dominates the substitution effect).

Demand for Wool

Raw wool is essentially an intermediate good that requires further processing into various textile products before being purchased by consumers. Since the focus of this model is on sheep, and given the complexity of the textile sector, we specify a farm-level demand function for wool that incorporates both input demand for wool and the final demand for wool textiles. This function specifies that the farm-level demand for raw wool increases as the price of raw wool decreases, the price of competing fibers (e.g., cotton) increases or consumer income increases.

Live Sheep and Wool Production

The production of live sheep and raw wool occurs jointly. Because of the intermediate-run nature of our model, we allow sheep producers in all regions to change the mix of the pounds of live sheep and raw wool produced by changing the composition of breeds in the herds in each region as the price of live sheep changes relative to the wool price.[11] For example, an increase in the price of wool will lead producers to switch towards wool breeds of sheep relative to meat-type sheep breeds. The willingness of sheep producers to respond to relative live sheep and wool price changes is allowed to vary between regions.

To produce live sheep and raw wool requires a set of inputs, such as feed grains, pasture, labor, facilities, etc. NAFTA has been predicted to have a significant impact on feed grain prices, particularly in Mexico (Grennes and Krissoff, 1993; U.S. Department of Agriculture, September 1992), implying changes in the cost of producing live sheep and raw wool. Because the sheep sector is not a large user of feed grains, we treat the change in feed grain price as exogenous and use the estimates of Grennes and Krissoff in the model.

A critical issue in assessing the impacts of NAFTA is how easily inputs, such as family labor and certain types of capital (e.g., grazing lands) can move into or out of the sheep sector as sector returns change in each region. For example, as the returns to live sheep and raw wool production decrease, do producers leave the industry quickly? The degree to which resources do move into or out the sheep industry determines the overall supply response of live sheep and raw wool, and plays a major role in determining the magnitude and direction of price changes at the farm-level.

In our model, the level of non-feed resources employed in the sheep sector is determined by equating the input demand for those resources with their supply.[12] Input demand for non-feed inputs is a decreasing function of its own price and an increasing function of the size of the sheep sector. The supply of the non-feed input is an increasing function of its own price. The greater the responsiveness of input demand and/or input supply is to changes in the price of the non-feed input, the more easily the non-feed input can move into or out of the sheep sector, and the greater the supply response.

Mutton and Lamb Production

The sheep processing sector purchases live sheep, along with other inputs such as labor and capital, to produce a single processed mutton and lamb product.[13] Because the sheep processing sectors are relatively small components of the domestic economies in each region, they have relatively small impacts on the domestic input markets (e.g., labor and capital). Thus we treat the prices of all non-sheep inputs into sheep processing as constant.

The input demand for live sheep is based on profit maximizing behavior by the processing firms. An increase in the level of mutton and lamb production or a decrease in the live sheep price leads to an increase in quantity of live sheep demanded.[14] The responsiveness of the input demand for live sheep to a change in the price of live sheep will be the same across all regions as long as all sheep processing firms employ the same technology.

Model Formulation and Solution

The partial equilibrium model described above is represented by a system of 51 equations.[15] There are five specific blocks of equations in the model. The first block contains the demand equations for mutton and lamb, live sheep, raw wool and non-feed input into the sheep sector in each region. The second block in the model is composed of the supply equations for live sheep, raw wool and non-feed input supply equation in each region.[16] The third block of equations contains the zero profit conditions that ensure no economic profits in the sheep processing and sheep sectors in each region. The fourth block of equations in the model contains the equilibrium, or market-clearing conditions. These conditions state that the demand for any product must equal its supply in an equilibrium. Finally, the last block of equations contains the price linkage equations that introduce the U.S. and Mexican tariffs into the model. All tariffs are ***ad valorem***, or a fixed percentage of the price of the

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[11] We employ a Constant Elasticity of Transformation (CET) production possibilities frontier to represent the potential to substitute between pounds of raw wool and live sheep.

[12] Due to lack of detailed production budgets in Mexico and other countries, we aggregate all non-feed inputs into a single non-traded input. This aggregation does not affecr the accuracy of the model's results as long as the relative prices of the non-feed inputs remain constant after the reduction in U.S. and Mexican tariffs.

[13] An aggregated mutton and lamb product is employed due to a lack of information on production and consumption of specific cuts of mutton and lamb in Mexico and ROW. Again, as long as the relative prices of particular mutton and lamb cuts remain constant, this aggregation will not effect the model's results.

[14] Wohlgenant (1989) has found that in the long run, beef and pork packers may substitute between the live animal inputs and other inputs in producing processed meat products. This contradicts the traditional assumption of fixed input proportions.

[15] The model is solved using a Lotus 1-2-3 spreadsheet. A complete description of the model equations and the Lotus spreadsheet are available from the authors upon request.

[16] A supply function for mutton and lamb products is not included in the model because it is redundanr with the zero profit condition (Diewert, 1981).

imported commodity. For the importing region, the domestic price becomes one plus the *ad valorem* tariff rate times the price of the good; this value is converted into the domestic currency in the foreign region.

Data Requirements

To implement our partial equilibrium model empirically requires information on input cost shares, revenue shares, expenditure shares, production shares, consumption shares, demand elasticities, supply elasticities and percentage changes in the exogenous variables (i.e., other meat prices, income, feed grain prices, tariff rates). Table 1 lists the base model parameters and exogenous variable values used in this analysis.[17] Data sources for the sheep processing sector, sheep sector and exogenous parameters are given sequentially below.

Table 1. Model data, elasticities and exogenous variable values.

	U.S.	Mexico	ROW[a]
Sheep Processing Sector:			
Consumption of mutton and lamb by region of origin (1,000 MT):			
U.S.	159.5	2.0	2.5
Mexico	0.1	25.9	0.0
ROW	19.0	9.2	6,883.8
Expenditure shares by region:			
U.S. (a_{1j})	0.917	0.001	0.082
Mexico (a_{2j})	0.059	0.734	0.207
ROW (a_{3j})	0.001	0.0	0.999
Retail demand elasticities:			
Mutton and lamb (η_{LL})	-0.7	-0.6	-0.45
Beef (η_{LB})	0.0	0.16	0.06
Pork (η_{LP})	0.13	0.20	0.10
Poultry (η_{LC})	0.05	0.20	0.05
Income (ε_L)	0.13	0.44	0.51
Elasticity of substitution (σ_i)	1.5	3.0	3.0
Live sheep input cost share (cs_L)	0.35	0.45	0.35
Live sheep input demand elasticity (γ_{ss})	-0.47	-0.40	-0.47
Sheep Sector:			
Raw wool:			
Production (1,000 MT)	39.5	4.5	2946.0
Consumption (1,000 MT)	64.1	8.0	2917.9
Demand elasticities for raw wool:			
Wool price (η_{ww})	-0.41	-0.5	-0.5
Income (ε_w)	0.1	0.4	0.3
Live sheep:			
Head slaughtered (1,000 hd)	5,585	1,397	n/a[b]
Exports (imports) (1,000 hd)	777	(777)	n/a[b]
Production of slaughter animals	6,362	620	n/a[b]
Elasticity of transformation (σ_{iT})	-0.1	-0.1	-0.1
Feed input cost share (c_{gs})	0.3	0.15	0.2
Revenue share:			
Live sheep (β_{is})	0.76	0.75	0.7
Raw wool (β_{iw})	0.24	0.25	0.3
Non-feed input in sheep sector:			
Supply elasticity (μ_i)	0.7	0.39	0.393
Input demand elasticity (λ_{π})	-0.1	-0.05	-0.067
Percent Change in Exogenous Variables:			
Price of beef (P_{iB})	-0.1	-0.3	0.0
Price of pork (P_{iP})	0.1	-1.1	0.0
Price of poultry (P_{iC})	0.1	3.0	0.0
Income (I_i)	0.1	2.0	0.01
Price of feedstuffs (P_{iG})	1.1	-16.0	1.0

[a] ROW = rest of the world.
[b] ROW live sheep is assumed to be non-traded.

Before embarking on a discussion of specific model parameters, we wish to note the difficulty in obtaining some of these parameters. In several instances noted below we were unable to find reliable point estimates of parameter values. For these cases we specify a reasonable range of values and do extensive sensitivity analysis that ensure our model results are robust.[18]

Sheep Processing Sector. Information on the levels of production, trade and consumption of mutton and lamb for each region are obtained from the United Nations (FAO Production and Trade Yearbooks, 1992) and the U.S. Department of Agriculture (USDA-FATUS, 1992). The first three rows in Table 1 list the levels of mutton and lamb consumption and production by region of origin. Reading down a column gives the level of mutton and lamb consumption in a region. For example, consumers in the U.S. purchased 159,500 metric tons (mt) of mutton and lamb from U.S. sheep processors, plus 19,100 mt from Mexican and ROW sheep processors (for a total mutton and lamb consumption of 178,600 mt). Reading across a row shows the destination of mutton and lamb production from a given region. Again, using the U.S. as an example, 159,500 mt of U.S. mutton and lamb production is sold to U.S. consumers, while 4,500 mt is exported to Mexican and ROW consumers (total U.S. mutton and lamb production is 164,000 mt). These data are used to determine the share of mutton and lamb production in region j consumed in region i (e_{ji}) and the consumption share mutton and lamb from region j consumed in region i (a_{ij}).

Retail demand elasticities for total mutton and lamb consumption are obtained from several sources. The

[17] The base year for our model is 1991.

[18] It has been our experience that the direction of change predicted by static partial equilibrium models are fairly robust over a realistic range of parameters.

own-price demand elasticity for mutton and lamb in the U.S., as well as the beef and pork cross-price elasticities, are obtained from TAMRC (1991). Sullivan et al. (1989) supply the own-price, cross-price and income elasticities for mutton and lamb in Mexico and the ROW, plus the income elasticity for the U.S. Unfortunately, we are not aware of a source for the elasticity of substitution between mutton and lamb (σ_i) from the different regions. We assume that consumer loyalty to mutton and lamb from a specific region is not extremely strong and that there is an elastic response to relative price changes in mutton and lamb in each region. In addition, because food composes a larger percentage of consumers' budgets in Mexico and the ROW, we assume that consumers in those regions are more sensitive to relative price changes than U.S. consumers. Thus we assume a value of σ_i of 1.5 for the U.S. and 3.0 for Mexico and the ROW.[19] Due to the degree of uncertainty concerning these demand elasticities, we consider a range of possible values in a sensitivity analysis discussed below.

The last two sets of parameters for the sheep processing sector are the input cost share of live sheep (c_{sL}) and the input demand elasticity for live sheep (γ_{ss}). The live sheep input cost share represents the value of live sheep in the retail mutton and lamb product, or a farm value share at the retail level. For the U.S., the farm value share is determined by dividing the price of market lamb in December 1990 (USDA Livestock, Meat and Wool Market News) by the average U.S. retail mutton and lamb price in December 1990 (American Lamb Council), converted to a live-weight basis. We assume that the farm value share in the ROW is the same as the U.S. but in Mexico the farm value share is higher than in the U.S. due to relatively lower non-sheep input costs, such as labor, compared to the U.S. Finally, the live sheep input demand elasticity is equal to the non-sheep input cost share (or one minus the live sheep input cost share) times the elasticity of substitution between live sheep and non-sheep inputs. Based on similarities between beef and sheep processing, we apply Wohlgenant's estimate of 0.72 for elasticity of substitution in beef and veal processing to the sheep processing sector in all regions. By applying the same elasticity of substitution across regions, we assume the technology employed in sheep processing is the same in all regions. Given the level of uncertainty regarding γ_{ss}, we again consider a range of values in a model sensitivity analysis.

Sheep Sector. Information on the level of raw wool production and trade is obtained from the FAO Production and Trade Yearbooks (1992). Consumption in a region is equal to production plus imports minus exports. From this data we determine the values of the parameters s_{iw}, the share of world wool production in region i, and e_{iw}, the share of world wool consumption in region i. The own-price and income demand elasticities for raw wool are obtained from Rosson et al. (1993).

The level of live sheep production is determined from the number of lamb and ewes slaughtered in each region (FAO Production Yearbook, 1992), and number of live sheep traded (USDA-FATUS, 1992). The number of live sheep slaughtered represents the total demand for live sheep; by adding exports and subtracting imports one obtains the number of live sheep produced. The share of U.S.-Mexico live sheep production (s_{is}) and share of U.S.-Mexico live sheep demand (e_{is}) are determined from this data.

In addition to the levels of production and consumption of live sheep and raw wool, we also must specify parameter values for live sheep and raw wool supply responsiveness and input demand parameters for the sheep sector. The elasticity of transformation (σ_{iT}) determines the responsiveness of sheep producers to changes in relative live sheep and raw wool prices. Even though producers may change the breed composition of their herds in the intermediate run due to changes in relative live sheep and raw wool prices, biological constraints prevent them from producing all wool or all live sheep for slaughter. Thus we assume a relatively small value for the σ_{iT} (-0.1), which is set equal across all regions. The revenue share of live sheep (β_{is}) and raw wool (β_{iw}) in the U.S. are obtained from the U.S. Department of Agriculture (Agricultural Statistics, 1991). Because Mexican and ROW producers generally produce high-quality raw wool, their raw wool revenue shares are assumed to be higher than for U.S. producers. The cost share of feed inputs (c_{gs}) used by U.S. sheep producers is based on information in the SID Sheep Production Handbook (American Sheep Industry Association, 1992).[20] Because U.S. producers feed out a larger percentage of slaughter animals than Mexico and ROW producers, the feed cost shares are lower in Mexico and the ROW. Finally, the aggregate supply response to an increase in live sheep and raw wool prices is equal to ($\mu - \lambda_{rr}$), where μ is the non-feed input supply elasticity and λ_{rr} is the non-feed input demand elasticity. Sullivan et al. (1989) estimate that the supply response for the sheep sector is 0.80 in the U.S., 0.44 for Mexico and 0.46 for the ROW.[21] Because sheep producers can not readily substitute between feed and non-feed inputs, the non-feed input demand elasticity is assumed to be much smaller, in absolute terms, than the supply elasticity of the non-feed input.

Exogenous Parameter Values. Values of the exogenous changes in the price of beef, pork, poultry and

[19] These values are within the range used by other empirical studies. For example, Grennes and Krissoff (1993) assume an elasticity of substitution across products equal to 3.

[20] We assume a lamb is fed from 50 to 110 pounds and requires 7 pounds of feed per pound of gain. The feed cost share is determined by dividing the cost of feed (valued at $100 per ton in 1991) by the total value of the live animal (valued at $60 per cwt) plus the raw wool (based on the historic raw wool cost share). This yields a feed cost share of approximately 0.3 for U.S. sheep producers.

[21] Sullivan et al. (1989) do not specify a length of run for their elasticities. While we presume these elasticities represent an intermediate-run response, we include the overall supply response by the sheep sector in our sensitivity analysis.

feedstuffs for the U.S. and Mexico from NAFTA are obtained from Grennes and Krissoff (1993). Unfortunately Grennes and Krissoff do not explicitly estimate changes in regional income in their model. Brown et al. (1992) estimate that the gross domestic product (GDP) will increase by 1.6% in Mexico and 0.1% in the U.S. from NAFTA. Using a different model, Burfisher et al. (1992) estimate that the increase in GDP ranges from 0.1 to 7.4% for Mexico and -0.2 to 0.5% for the U.S. under NAFTA. We take a middle ground between these two estimates and assume a real GDP increase of 0.1% in the U.S. and 2.0% in Mexico.[22]

Unfortunately, existing empirical analyses of NAFTA generally do not cover a third region (ROW) or have a higher level of commodity aggregation than in our model. Given that most of the benefits from NAFTA should only accrue to the U.S., Canada and Mexico, we assume that the impact on the ROW is limited. Real income growth in the ROW is assumed to be one-tenth the U.S. income growth. Because of limited trade in processed meat products, we assume no effect on beef, pork and poultry prices in the ROW. The only commodity in our model that will likely experience a significant price change in the ROW is feed grains, because the U.S. is a large supplier of this commodity. Thus the ROW feed grain price change is assumed to equal the feed grain price change in the U.S.

Table 2. Effects of removing U.S.-Mexican tariffs on live sheep and mutton and lamb under NAFTA.

	Percent of change			
Variable/Region	**Point estimate**	**SD[a]**	**Minimum**	**Maximum**
Market price:				
Live sheep:				
U.S.	1.6	0.5	0.5	4.6
Mexico	-8.4	0.5	-9.5	-5.3
ROW	0.2	0.07	0.0	0.5
Raw wool	0.2	0.1	0.0	0.9
U.S. mutton and lamb:				
U.S.	0.6	0.2	0.2	1.8
Mexico	-9.4	0.2	-9.8	-8.2
Mexican mutton and lamb	-3.8	0.5	-5.0	-2.3
Production:				
Live sheep:				
U.S.	0.9	0.4	-0.04	2.3
Mexico	-1.4	1.1	-4.9	1.7
ROW	-0.1	0.03	-0.3	0.0
Raw wool:				
U.S.	0.8	0.4	-0.2	2.2
Mexico	-0.5	1.2	-4.3	2.9
ROW	-0.1	0.04	-0.3	0.0
Mutton and lamb:				
U.S.	-0.2	0.2	-1.1	0.4
Mexico	3.7	1.4	0.1	8.5
ROW	0.0	0.01	-0.1	0.01
Exports:				
U.S. live sheep	13.7	3.3	3.2	24.3
Mutton and lamb:				
U.S.	8.4	4.6	-1.2	18.7
Mexico	6.2	3.8	-1.1	15.2
Imports:				
Mutton and lamb:				
U.S.	0.4	0.5	-1.3	3.0
Mexico	-2.6	3.2	-12.3	5.0

[a] SD = standard deviation

Results and Discussion

The first column in Table 2 reports the model results simulating the removal of all live sheep and mutton and lamb trade barriers between the U.S. and Mexico using the base set of parameter values in Table 1. The main features of this simulation are a 10% reduction in the Mexican tariff on live sheep and mutton and lamb imports from the U.S. All results given in this paper reflect intermediate-run changes in prices and quantities from the base year of 1991.

We begin the discussion of the implications of the removal of the Mexican tariffs by focusing on the sheep sector in Mexico. Because removing the Mexican live sheep tariff eliminates the price wedge between Mexican live sheep prices and U.S. live sheep prices, the Mexican live sheep price falls by 8.4%. The reduction in the Mexican live sheep price in Mexico lowers the input costs of Mexican sheep processors, which increases their demand for Mexican live sheep.[23] This increase in processor demand helps to dampen the reduction in the live sheep price in Mexico. Also, the large reduction in Mexican feed grain prices from NAFTA helps to lessen the impact of the tariff removal by lowering input cost. But because fewer lambs are fed grains in Mexico, the effect of lower feed costs is minimal. In the short run, lower Mexican live sheep price leads to negative economic profits in the Mexican sheep sector. To restore an intermediate-run equilibrium (i.e.,

[22] These estimates represent one-time increases in GDP for the U.S. and Mexico that are attributed NAFTA, holding total factor endowments in the U.S. and Mexican economies constant.

[23] The increase in the quantity of live sheep demanded by Mexican sheep processors is due to the reduction in live sheep price (or a movement along the input demand schedule) and an increase in mutton and lamb production that shifts out the live sheep input demand schedule.

zero economic profits) in the Mexican sheep sector, resources (e.g., producers, grazing lands, etc.) must flow out of this sector. This exit of resources employed in the Mexican sheep sector results in a 1.4% drop in live sheep production in Mexico.

At first glance, NAFTA seems to be a double-edged sword for the Mexican sheep processors. They benefit from the reduction in the live sheep tariff because it reduces their input costs. On the other hand, the elimination of the tariff on U.S. mutton and lamb imports makes the U.S. product relatively less expensive for the Mexican consumer than the Mexican mutton and lamb. Indeed, the price of U.S. mutton and lamb in the Mexican market drops by 9.4%, compared to a 3.8% reduction in the price of Mexican mutton and lamb. But even in the face of a 20.8% increase in U.S. mutton and lamb exports into the Mexican market, Mexican sheep processors still expand their production by 3.7% due to an increase in the consumption of Mexican mutton and lamb by Mexican consumers.

There are two reasons for the increase in the consumption of Mexican mutton and lamb by Mexican consumers. First, because NAFTA does not eliminate Mexican tariffs on mutton and lamb imported from ROW, making it relatively more expensive than U.S. or Mexican mutton and lamb in the Mexican market, Mexican consumers substitute away from ROW mutton and lamb and consume more U.S. and Mexican products. In addition, the expected strong income growth in the Mexican economy from NAFTA boosts the demand for mutton and lamb products by Mexican consumers.

Because of the expansion of Mexican mutton and lamb production and the contraction of Mexican live sheep production, U.S. live sheep exports to Mexico increase by 13.7%. This increase in export demand, along with an increase in feed grain prices in the U.S. from NAFTA[24], leads to a 1.6% increase in the price of live sheep in the U.S. To meet the increase in export demand, more non-feed resources flow into the U.S. sheep sector, with U.S. live sheep production expanding by 0.9%.

The impact of NAFTA on the U.S. sheep processing sector is very small. Even though Mexican consumers increase their consumption of U.S. mutton and lamb, consumers in the U.S. reduce their consumption of U.S. mutton and lamb products. The decrease in consumption by U.S. consumers is due to changes in relative mutton and lamb prices in the U.S. market. Because of the increase in the U.S. live sheep price, which increases input costs for the U.S. sheep processors, the price of U.S. mutton and lamb increases by 0.6% in the U.S. market. However, because the removal of the Mexican live sheep tariff lowers input costs for the Mexican sheep processors, the price of Mexican mutton and lamb in the U.S. market decreases by 3.8%. Thus Mexican and ROW mutton and lamb are relatively less expensive for U.S. consumers compared to U.S. mutton and lamb, leading to a 6.2% increase in the consumption of Mexican mutton and lamb, a 0.4% increase in the consumption of ROW mutton and lamb and a 0.4% decrease in the consumption of U.S. mutton and lamb by U.S. consumers. Because the vast majority of the mutton and lamb produced by U.S. sheep processors is sold in the U.S. market, total consumption of U.S. mutton and lamb by U.S., Mexican and ROW consumers falls by 0.2%.

Finally, as expected, the removal of live sheep and mutton and lamb tariff under NAFTA has little effect on the price of raw wool. The contraction of the Mexican and ROW sheep sectors leads to a small reduction in the world supply of raw wool and a 0.2% raw wool price increase.[25]

Sensitivity Analysis. Because of the uncertainty in a number of model parameter values, we perform a sensitivity analysis to determine how robust the model results are to changes in the underlying parameter values. Table 3 lists the parameters that are included in the sensitivity analysis and their range of possible values. Because we do not know the probability distribution of these parameters, we assume a uniform distribution. Also, because certain parameters have a limited range of values (e.g., cost shares cannot be negative), using a uniform distribution allows appropriate end-points to be assigned to the probability distribution.

To determine the robustness of our results, each of the uniform probability distributions is randomly sampled and the model is resolved using the new parameter values. (All of the probability distributions are assumed to be independent of each other.) This step is repeated 3,600 times in order to determine the probability distributions of the endogenous variables in our model.[26] The standard deviation, the minimum value and the maximum value for each endogenous variable are reported in the last three columns of Table 2.

The point estimates of the market price changes are robust in our model. The predicted change in direction of live sheep, raw wool and mutton and lamb prices are robust within the range of possible parameter values identified in Table 3. For example, the U.S. price of live sheep always increases regardless of the parameter values used in the model. In addition, the standard deviations of our price point estimates are generally small relative to the magnitude of the predicted price change. This indicates that a large portion of the probability distribution for the market prices in the model are within a small range of the point estimates. For example, Figure 1 shows that the probability of a 0.9 to 2.3% increase in the U.S. live sheep price is approximately 0.87.[27]

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[24] In order to maintain a long-run equilibrium with zero economic profits, any increase in input cost must be accompanied by an increase in output price.

[25] The ROW sheep sector contracts slightly due to a reduction in export demand for mutton and lamb by Mexico.

[26] The Lotus add-in @Risk is used to perform the sensitivity analysis. The number of iterations in the sensitivity analysis is determined by the convergence criteria of the @Risk software.

[27] From Figure 1, the probability that the percentage change in the U.S. live sheep price in our model results is between 0.91 and 1.10 is approximately 0.08; the probability that the U.S. live sheep price is between 1.11 and 1.30 is approximately 0.15; and so forth.

The point estimates of changes in live sheep production are also robust in our model. Live sheep production in the U.S. increases while Mexican and ROW live sheep production decreases across the range of possible parameter values. Again, the standard deviations of the probability distributions are relatively small. Figure 2 shows that the probability of the U.S. live sheep production increasing between 0.3 and 1.5% is approximately 0.87.

The most variable results in our model are the percentage changes in raw wool and mutton and lamb production, and the level of live sheep and mutton and lamb trade between the U.S. and Mexico. For several endogenous variables such as the percentage change in U.S. mutton and lamb production, the model may predict either an increase or a decrease depending on the parameter values used. However, as shown in Figure 3, the probability of an increase in U.S. mutton and lamb production in our

Figure 1. Model probability distribution of percentage change in U.S. live sheep price from NAFTA.

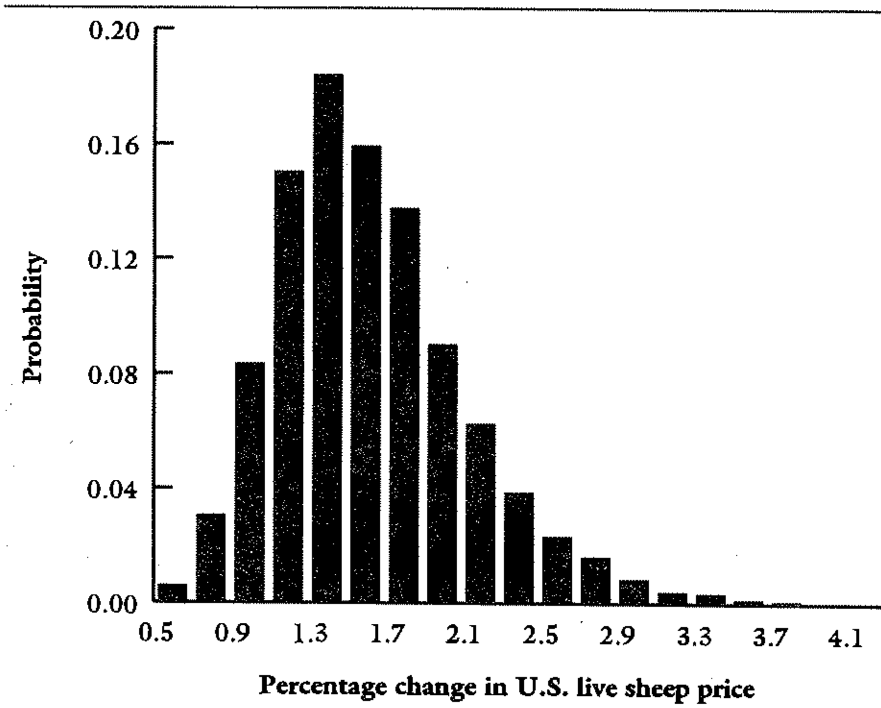


Table 3. Range of parameter values considered.

	U.S.		Mexico		ROW[a]	
	minimum	maximum	minimum	maximum	minimum	maximum
Sheep Processing Sector:						
Retail demand elasticities:						
Mutton and lamb (η_{LL})	-1.2	-0.2	-1.1	-0.1	-0.85	-0.05
Beef (η_{LB})	0	0.1	0.1	0.31	0.01	0.11
Pork (η_{LP})	0.01	0.25	0.05	0.35	0.01	0.19
Poultry (η_{LC})	0.01	0.09	0.01	0.39	0.01	0.09
Income (ε_L)	0.01	0.25	0.1	0.78	0.1	0.92
Elasticity of substitution (σ_i)	0	3.0	0	6.0	0	6.0
Live sheep input cost share (c_{sL})	0.3	0.4	0.35	0.55	0.3	0.4
Live sheep input:						
Demand elasticity (γ_{ss})	-0.84	-0.1	-0.7	-0.1	-0.84	-0.1
Sheep Sector:						
Demand elasticities for raw wool:						
Wool price (η_{ww})	-0.72	-0.1	-0.9	-0.1	-0.9	-0.1
Income (ε_w)	0.01	0.19	0.1	0.7	0.1	0.5
Elasticity of transformation (σ_{iT})	-0.2	0	-0.2	0	-0.2	0
Feed input cost share (c_{gs})	0.2	0.4	0.1	0.2	0.1	0.3
Non-feed input in sheep sector:						
Supply elasticity (μ_i)	0.1	1.3	0.1	0.68	0.1	0.69
Input demand elasticity (λ_{rr})	-0.19	-0.01	-0.09	-0.01	-0.12	-0.01
Exogenous variables:						
Price of beef	-0.2	0	-1.5	-0.1	–	–
Price of pork	0	0.2	-2.1	-0.1	–	–
Price of poultry	0	0.2	-0.9	-0.1	–	–
Price of feed grains	0.5	1.7	-26.0	-6.0	0.5	1.5
Income	0	0.2	1.0	3.0	–	–

[a] ROW = rest of world.

model is approximately 0.21. Finally, the relatively large standard deviations for the estimated changes in live sheep and mutton and lamb trade are due to the relatively small level of U.S.-Mexico trade in these commodities. Thus a small change in the absolute level of exports yields a large percentage change.

Conclusion

In general, the effects of NAFTA on U.S. sheep producers will be very modest. Through increased access to the Mexican market, U.S. live sheep production is estimated to increase by 0.9%, or an additional 50,000 head slaughtered. Also, the increase in export demand leads to a 1.6% increase in the U.S. live sheep price, or about $1.00 per 100 pounds (at 1991 average price). These increases in live sheep production and price yields approximately a $10.5 million (1991 dollars) or a 2.6% increase in total industry revenue to U.S. sheep producers from sheep and lamb sales. Given these modest increases, it is unlikely that many U.S. sheep producers will notice any changes from NAFTA in the near future.

Figure 2. Model probability distribution of percentage change in U.S. live sheep production from NAFTA.

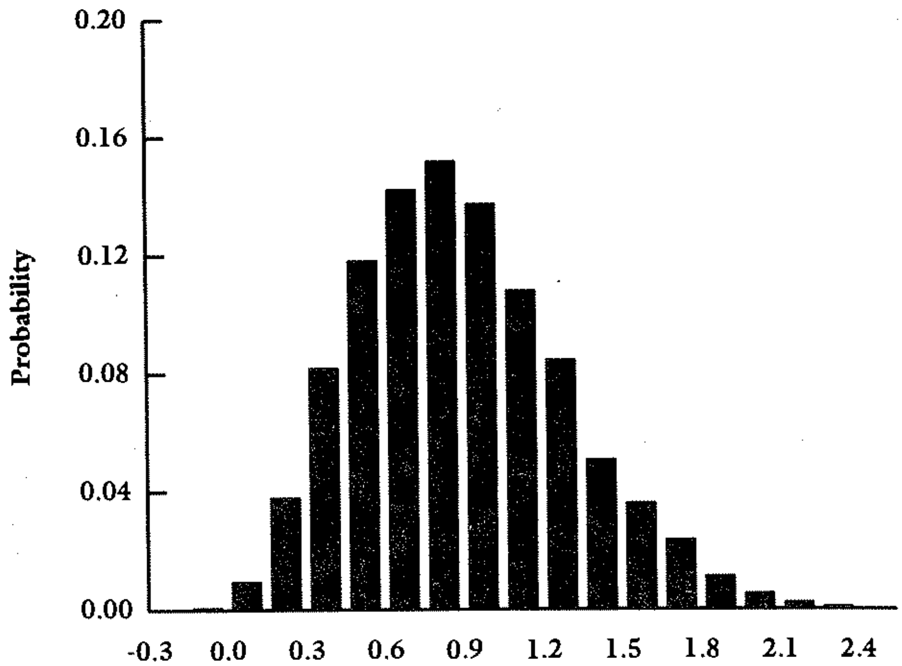
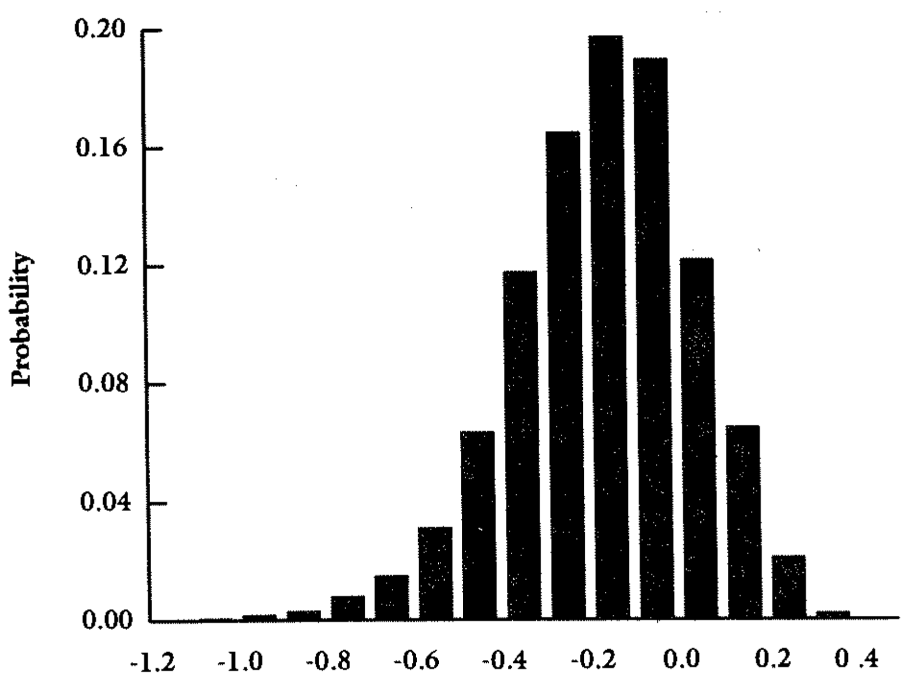


Figure 3. Model probability distribution of percentage change in U.S. mutton and lamb production from NAFTA.



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Effects of Breed and Previous Grazing Location on Performance of Feedlot Wethers[1]

P.G. Hatfield[2]

Summary

Rambouillet (R) and Columbia (C) wethers (average body weight [BW] = 36 kg) were used in a two-by-two factorial arrangement of treatments to evaluate the effects of breed and previous grazing location on feedlot performance. Wethers had previously been managed and grazed with their dams either unherded on desert (D) or herded on mountain (M) ranges. Treatment combinations were MR, MC, DC and DR with 24 wethers per treatment. Wethers were stratified by initial BW within treatment group with six wethers per pen and four pens per treatment. All wethers were given 115 g per wether per day of a commercially-prepared pelleted supplement and allowed ***ad libitum*** access to a diet that initially consisted of 30% whole barley and 70% chopped hay. The proportion of barley in the diet was increased until a diet of 80% whole barley and 20% chopped alfalfa hay was reached. Wethers were slaughtered after 57 days on feed at an average shrunk BW of 48.5 kg. Breed-by-previous grazing location interactions ($P < 0.07$) were detected for all feedlot variables except initial BW and dry matter intake (DMI), therefore data were analyzed as the simple effects of previous grazing location within breed. There were no differences ($P > 0.36$) between MR and DR wethers in any of the feedlot performance traits measured. Final BW (52.1 and 47.0 kg), average daily gain (ADG; 0.25 and 0.20 kg), DMI (1.5 and 1.4 kg per wether per day) and percent of NRC (1985) projected gain (105.1 and 84.2%) were higher ($P < 0.05$) for MC than DC wethers, respectively. The combination of breed with previous grazing location and management may be an important consideration in determining the performance of feedlot lambs.

Key words: feedlot lambs, desert range, mountain range, Rambouillet, Columbia.

Introduction

In 1989, the U.S. Sheep Experiment Station began a co-species grazing study involving sheep and cattle grazing traditional spring desert range from May until September. At the end of the first year, lambs from the co-species project weighed more at weaning than lambs from the mountain pastures (Walker, unpublished data). When both desert and mountain lambs were put in the feedlot, it was observed (but not documented) that mountain lambs tended to reach slaughter weight earlier than desert lambs.

Effects of breed and sex on feedlot lamb performance and carcass characteristics were reported by Fitzgerald (1986) and Lord et al. (1988). In addition, Ortega Reyes et al. (1992) investigated the effects of early diet training on post-weaning performance in lambs. However, no information is available on the interaction of lamb breed and previous grazing location on feedlot performance. The objective of our study was to evaluate the feedlot performance and carcass characteristics of Rambouillet and Columbia wethers which had previously grazed either desert or mountain ranges.

Materials and Methods

Rambouillet (R) and Columbia (C) wethers (average birth date: April 2) were used in a 57-day experiment to evaluate the effects of lamb breed and previous grazing location on feedlot lamb performance and carcass characteristics. Wethers and dams had previously been managed and grazed either unherded on sagebrush/bunchgrass desert range (D) or herded on an alpine mountain meadow (M) range (Table 1).

On both D and M ranges, cursory assessment of diet quality was deter-

[1] The author acknowledges the technical assistance of E. Vadnais and J. Hopkins.

[2] USDA-ARS, U.S. Sheep Experiment Station, Dubois, ID 83423. Voice phone: (208) 374-5307, fax: (208) 374-5582.

mined by collecting ingesta samples from three ruminally-cannulated mature wethers grazing the study site. Rumens were completely evacuated before wethers were allowed to graze for 30 minutes. After the 30-minute grazing period, ruminal ingesta samples were collected and the original ruminal contents replaced. Samples from all experiments were dried at 60 °C for 24 hours, then air-equilibrated and ground through a Cyclone mill (1-mm screen), air-equilibrated again and stored in airtight containers. Ingesta samples were analyzed by animal-within-previous grazing location and then averaged within location (Table 2). Forage and diet samples were collected in early June on D and mid-July on M.

Wethers from D were part of a co-species grazing project in which ewes and lambs were moved to D pastures after shed-lambing in April. Wethers grazed D pastures with their dams until weaning in August. Wethers from M were shed-lambed at the same time as D wethers. After lambing, ewes and M wethers grazed spring desert pasture similar to D wethers. In early July, M wethers were moved to subalpine range in the Centennial Mountains on the Montana-Idaho border, where they grazed with their dams until weaning in August.

Immediately after weaning, 96 wethers were selected (from a total of 550 wethers) based on health and uniformity of age and weight (average BW = 36 kg). Treatment combinations were MR, MC, DC and DR with 24 wethers per treatment. Wethers were fed in outdoor pens (25 m^2) with six wethers in each pen and four pens per treatment. Wethers were fed twice daily at 0730 and 1600 hours. Feed offered was recorded daily and refusals were recorded when more than 500 g of refused feed accumulated in the feed bunk. When the wethers entered the feedlot, they received a diet composed of 30% whole barley, 70% chopped alfalfa hay and 115 g per wether per day of a commercially-prepared pelleted supplement. The amount of barley in the diet was increased by 10% every third day until a finishing diet consisting of 80% whole barley and 20% chopped alfalfa hay (plus supplement) was reached. Wethers were fed this finishing diet for 42 days. The average shrunk weight at the end of the feeding period was 48.5 kg.

Wethers were weighed at the beginning and end of the study. Weights were recorded after an overnight shrink without feed or water. Data collected included BW gain and dry matter intake. Feed-to-gain ratios were calculated. Percent of NRC (1985) projected BW gain was calculated based upon estimated energy intake.

Pen was the experimental unit for feedlot variables. Wethers within treatment were stratified by initial starting BW. Initial models included the effects of breed, previous grazing location, pen and all two-way interactions, with pen-by-breed-by-previous grazing location as the error term. No pen-by-previous grazing location or pen-by-breed interactions were detected ($P > 0.14$), therefore these terms were added to the error term. Lamb age and sire were also included in the initial model. Variables that demonstrated a breed-by-previous grazing location interaction were analyzed as a simple one-way effect of previous grazing location within breed.

Table 1. Forage composition and availability on desert and mountain ranges.

Location	Grass, %	Forbs, %	FA[a], kg\ha
Desert	69	31	297.2
Mountain	31	69	328.5

[a] FA = forage availability.

Table 2. Chemical composition (100% dry matter) and *in vitro* organic matter digestibility of ingesta samples collected on desert and mountain ranges and chopped alfalfa hay fed during the feedlot period.

Location	CP[a]	NDF[b]	Ash	IVOMD[c]
Desert	15.4	58.2	12.8	63.1
Mountain	14.8	52.1	9.8	64.9
Chopped alfalfa hay	15.7	53.1	8.3	69.6

[a] CP = crude protein.
[b] NDF = neutral detergent fiber.
[c] IVOMD = *In vitro* organic matter digestibility.

Results and Discussion

No effects ($P > 0.26$) of lamb age or sire were detected for any variables measured. These variables were dropped from the model. Breed-by-previous grazing location interactions were detected ($P < 0.07$) for all feedlot performance variables except initial BW and daily DMI. Therefore, results presented are the simple effects of previous grazing location within breed.

Initial BW, final BW, ADG, DMI and percent of NRC (1985) projected gain were higher ($P < 0.05$) for MC than DC (Table 3). MC had a lower ($P = 0.08$) feed efficiency than DC. There were no differences ($P > 0.36$) in any of the feedlot performance traits measured for MR and DR (Table 4).

There were no differences ($P > 0.36$) between MR and DR for any of the variables measured (Table 4), indicating that previous grazing location had no effect on the performance of R wethers. Previous grazing location had a major influence on feedlot performance of C wethers, with DC wethers being 20% less efficient than MC in terms of NRC (1985) projected gain based on energy intake.

No apparent reason was identified to explain the effect of previous grazing location on the feedlot performance of C wethers but not R wethers. Although cursory forage and digesta analyses indicated little difference in M and D grazing sites, one would expect forage quality to decline sooner on the D range than on the M range. If so, a decline in forage quality on D should have benefitted the D wethers in the feedlot in terms of compensatory gain; however, this was not the case.

The M wethers were handled more frequently and experienced a greater diversity of range sites than the D wethers. In addition, M wethers were herded, worked with dogs and had guardian dogs present. This was not the case for D wethers. Possibly M wethers were more adaptable to their new feedlot environment than D wethers. Reid and Mills (1962) and Bassett and Hinks (1969) found that the degree of stress an animal experiences depends in part on adaptation. Further, Waldo et al. (1961) and Noblitt et al. (1963) found that stress can reduce digestibility of nutrients. Although previous grazing location and the level of management imposed upon animals may influence the level of adaptation and consequently performance, this does not explain the breed-by-previous grazing location interaction, unless C wethers are less adaptable and experience more stress than R wethers.

Conclusions

This study demonstrates an interaction between breed and previous grazing environment. Although the biological events that lead to this difference are not clear, the combination of breed and previous grazing location and management may be an important consideration in determining the performance of feedlot lambs.

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Table 3. Effects of previous grazing location on feedlot performance of Columbia wethers.

Item	Mountain	Desert	SE[a]	P[b]
Initial wt, kg	37.8	36.4	0.30	0.12
Final wt, kg	52.1	47.0	0.24	0.001
Daily gain, kg	0.25	0.20	0.01	0.05
DMI, kg·head^{-1}·d^{-1}	1.50	1.40	0.01	0.003
Dry feed/kg gain	6.0	7.2	0.32	0.08
% NRC projected gain	105.1	84.2	4.34	0.04

[a] SE = standard error of the means.
[b] P-value associated with mean comparison.

Table 4. Effects of previous grazing location on feedlot performance of Rambouillet wethers.

Item	Mountain	Desert	SE[a]	P[b]
Initial wt, kg	36.0	35.3	0.44	0.36
Final wt, kg	47.9	46.9	0.89	0.46
Daily gain, kg	0.22	0.21	0.01	0.75
DMI, kg·head^{-1}·d^{-1}	1.46	1.41	0.05	0.55
Dry feed/kg gain	6.6	6.6	0.33	0.96
% NRC projected gain	90.5	91.1	5.92	0.95

[a] SE = standard error of the means.
[b] P-value associated with mean comparison.

A Review of Montana Winter Range Ewe Nutrition Research[1,2]

V.M. Thomas[3] and R.W. Kott[3]

Summary

Research has been conducted over the past 50 years at Montana State University to determine the best low-cost and biologically efficient method of wintering ewes on range without reducing lamb and wool production. Research has determined that supplementation is cost effective most winters in Montana. Forage intake was not reduced when supplements were fed at 0.2 to 0.3% of ewe body weight. Body condition entering the winter influences ewe productivity and response to supplementation. Ewes can lose some body condition and maintain desired levels of productivity if they enter the winter in good body condition. Alternate day supplementation is a viable management alternative for range sheep producers. Energy supplements are cost effective when ewes can afford to lose some body weight, range forage is available and winter weather is mild. However, protein supplements should be fed when ewes can not afford to lose body weight and need to gain weight or weather conditions reduce forage availability and intake. Economic analyses are presented in this paper by comparing additional cost of supplements compared to additional pounds of lamb and wool produced.

Key words: winter range, pregnancy, ewe, supplementation.

Introduction

The goal of a range sheep operation is to meet the nutritional needs of the flock with range forage and minimize the use of supplemental and harvested feeds while maintaining economical lamb and wool production. In Montana, native range forage supplies the nutritional base for optimal production during spring and summer months provided forage availability is adequate. However, winter range forage quality is often not adequate to support optimal performance and ewes may need to be supplemented. The amount and type of supplement needed are extremely variable among ranges and years. The successful operator must be able to assess range condition, nutrient needs and body condition of the ewes to determine the quantity and type of supplement needed to optimize production.

Research has been conducted over the past 50 years at Montana State University to determine the best economical and biologically efficient method of wintering range ewes. This paper will review the research on winter range nutrition of ewes during pregnancy. Where appropriate, the value of lamb and wool minus supplement costs has been calculated. Similar monetary values for lamb, wool and supplements were used in these calculations.

Wintering Mature Ewes

Forage Quality.

During the winters of 1984-85, 1985-86, 1991-92 and 1992-93, researchers determined the nutritional value of winter range forage using ruminally cannulated ewes at the Red Bluff Research Ranch near Norris, MT. This technique is a more accurate measure of diet quality than clipped samples since only consumed forage is sampled. Protein content of the native foothills winter range forage was approximately 7.0% in three out of four years (Table 1). However, in 1992-93 protein content decreased to 4.5%. This decrease was because of less fall regrowth and more snow cover, which prevented ewes from consuming new fall growth. Protein requirement of a 154-pound ewe during the winter is 9.3% (National Research Council [NRC], 1985); therefore, protein appeared to be limiting in all years and most limiting in 1992-93.

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[3] Montana State University, Bozeman, MT 59717.

Forage and Nutrient Intake.

Quantity of forage consumed by ewes on winter range influences type and quantity of supplemental feed required. Harris et al. (1989) reported that ewes grazing Montana winter range consumed 1.7 to 1.8% of their body weight in dry matter (DM) daily (Table 2). Neutral detergent fiber was used as an internal marker to determine digestibility and total fecal collections taken to predict forage intake. Supplementation of 0.33 pounds of a 20% protein barley-based supplement did not reduce forage intake by gestating ewes grazing winter range. Soder (1993), using chromic oxide boluses as an external marker, reported lower forage intakes than those reported by Harris et al. (1989). This difference may have been due to different markers used to estimate forage intake and inclement winter weather in 1992-93 which reduced quality and availability of forage and grazing time. Supplement intake in these studies was approximately 0.2% of ewe body weight. This quantity of supplement was probably not great enough to cause supplement to substitute for forage. Estimated total digestible nutrients (TDN) intakes from data of Harris et al. (1989) provided 87 and 100% in 1985-86 and 76 and 83% in 1986-87 of the National Research Council (NRC; 1985) energy requirements for non-supplemented versus supplemented ewes, respectively. Protein intake for non-supplemented and supplemented ewes, respectively, was 74 and 90% in 1985-86 and 56 and 74% in 1986-87 of NRC (1985) requirements. Therefore, supplementation was required to meet NRC (1985) requirements for energy and protein. In years when forage dry matter intake is reduced, protein becomes much more limiting than energy. If a 154-pound ewe consumes 1.8 to 2.0% of her body weight daily of dry matter containing 7.0% protein, protein consumption provided by forage would be 0.19 to 0.22 pounds. The protein requirement during the first 105 days of pregnancy is 0.29 pounds (NRC, 1985). Therefore, the ewe requires an additional 0.07 to 0.10 pounds of protein, which needs to be accomplished through supplemental feeding.

Supplementation on Winter Range.

Pregnant ewes grazing in Montana are commonly fed between 0.33 and 0.5 pounds of a grain-based supplement containing a small proportion of a plant protein source such as canola, soybean, cottonseed or safflower meals. Orcutt (1956) suggested that winter feeding resolves itself into the question, "When does my low-cost winter feeding program become expensive?" Most sheep producers know that it is easy to reach a point where feed-saving decreases production and therefore reduces profits. Ewes must be fed adequately during mid-pregnancy to ensure normal placental development (McCrabb et al., 1992). Poor placental development results in poor transfer of nutrients and oxygen to the fetus, increasing susceptibility to early lamb mortality.

Body condition at the beginning of the wintering period is an important variable influencing supplementation practices. Darroch et al. (1950) reported that supplemented ewes in good body condition during early pregnancy (approximately the first 100 days of pregnancy) gained more body weight than supplemented ewes

Table 1. Nutrient composition of ruminal extrusa collected during January, February and March from ruminally cannulated ewes at Red Bluff Research Ranch, Norris, MT.

Year	Crude protein, %	Neutral detergent fiber, %
1985-86[a]	7.7	67.9
1986-87[a]	6.3	74.0
1991-92[b]	7.1	62.8
1992-93[b]	4.5	74.8

[a] Harris et al. (1989).
[b] Soder (1993).

Table 2. Effect of year and supplementation on forage dry matter intakes of ewes grazing winter range at the Red Bluff Research Ranch, Norris, MT.

	Supplement treatments	
	No supplement	0.33 pounds of supplement (20% CP[a])
1985-86:[b]		
Forage DM intake, pounds per day	2.5	2.4
% of body weight	1.8	1.7
1986-87:[b]		
Forage DM intake, pounds per day	2.3	2.1
% of body weight	1.7	1.5
	All ewes supplemented with 0.33 pounds[c]	
1991-92:[c]		
Forage DM intake, pounds per day[d]	2.5	
% of body weight[d]	1.6	
1992-93:[c]		
Forage DM intake, pounds per day[d]	2.0	
% of body weight[d]	1.3	

[a] CP = crude protein.
[b] Harris et. al. (1989).
[c] Soder (1993).
[d] Year effect ($P < 0.01$).

in poor body condition. He suggested that ewe body condition appeared to be the most important factor influencing number of lambs born and weaned. If ewes are in moderately good condition (body condition score greater than 3.0), they do not need to gain weight (Orcutt, 1956) until late pregnancy.

Daily supplementation on winter range is probably not necessary. Thomas et al. (1992a) reported that ewes fed 0.66 pounds of a supplement containing 18% crude protein on alternate days while grazing winter range had similar performance to those supplemented daily with 0.33 pounds (Table 3). He concluded that, after mating, ewes in good body condition may be supplemented on alternate days while grazing winter range.

Two winter feeding trials were conducted (1985-86, 1986-87) at the Red Bluff Research Ranch (Thomas et al., 1990). The objective of the research was to evaluate the productivity of pregnant ewes fed lasalocid (Hoffman LaRoche, Inc., Nutley, NJ) and two supplement levels (0.33 vs. 0.50 pounds of a 20% protein supplement) while grazing winter range (Thomas et al., 1990). Lasalocid prevents coccidiosis in sheep and also changes ruminal fermentation of carbohydrate to favor greater propionate production, as well as decreasing ruminal breakdown of protein. Lasalocid has been shown to improve the feed efficiency of feedlot lambs (Thomas and Dahmen, 1986). Five hundred ewes were used each year. Lasalocid was fed at a daily rate of 70 mg per head. Ewes were fed the supplements for 84 days until shearing. Following shearing (approximately 30 days before lambing) ewes were removed from winter range and fed hay and grain to meet NRC (1985) requirements for a pregnant ewe the last 42 days of pregnancy.

Feeding lasalocid in a range supplement improved the pounds of lamb weaned per ewe exposed to the ram (Table 4) and the value of lamb and wool was $3.40 greater for lasalocid-supplemented ewes. Feeding ewes 0.5 pounds of supplement increased ewe weight gain and grease fleece weights compared with those of ewes fed 0.33 pounds of supplement; however, lamb production and dollar return was not improved compared to feeding 0.33 pounds of supplement. Therefore, 0.33 pounds of supplement appeared to be satisfactory in these studies.

Chittenden et al. (1935) compared the production of ewes supplemented with either corn, cottonseed cake or a 25% protein pellet, and found it similar to that of non-supplemented ewes. The range was largely southern slopes, dominated with bluebunch wheatgrass and several varieties of sagebrush, mountain mahogany, soap weed and other weeds. Their data supports the idea that if the range is a mixed range and ewes are in good body condition entering the winter, minimal supplementation is required. In contrast, an early study at Utah State University in the Great Basin (Clanton, 1957) reported that supplementation with a 25% protein pellet (barley and cottonseed meal) at a rate of 0.25 pounds daily improved the pounds of lamb weaned compared to ewes fed corn or not supplemented

Table 3. Influence of alternate day supplementation on ewe body weight change and lamb production of ewes grazing winter range.[a,b]

Item	Daily	Alternate day
Body weight change, pounds	0.4	0.2
Grease fleece weight, pounds	9.7	9.4
Lamb weaned, %	115.8	109.3
Lamb weaned, pounds	75.9	71.4
Value of lamb and wool[c]	$55.20	$52.20

[a] Thomas et al. (1992a).
[b] Average of two feeding trials (1987-89) representing 538 ewe observations. Ewes were supplemented in the morning prior to turnout on winter range. Supplement was a barley-based pellet containing 20% CP.
[c] Lamb and wool value was $0.60 and $1.00 per pound, respectively.

Table 4. Influence of supplement level and lasalocid on ewe body weight change, wool production and ewe productivity.[a]

	Supplement level		Lasalocid intake, mg/day	
Item	0.33 lb	0.50 lb	None	70
Weight change, pounds[b]	8.8	10.8	10.1	9.7
Grease fleece weight, pounds[b]	8.8	9.2	9.0	9.0
Lambs weaned, %[b]	88.1	89.0	83.7	93.4
Lamb production per ewe, pounds[b]	54.5	53.7	51.2	57.2
Value of lamb and wool minus supplement costs[c]	$39.4	$38.2	$37.2	$40.6

[a] Thomas et al. (1990).
[b] Weight change and grease fleece weight differ among supplement level ($P < 0.05$). Lambs weaned and lamb production differ among lasalocid treatments ($P < 0.01$).
[c] Supplements fed for 84 days. Value of lamb and wool used were $0.60 and $1.00 per pound, respectively. Supplement costs were $140.00 per ton for no lasalocid and $160.00 per ton for the lasalocid supplement.

while grazing a grass-shrub range during the winter.

Van Horn et al. (1959a) conducted an early winter nutrition experiment that began in 1948 and concluded in 1952. The supplementation study was designed to determine the influence of protein supplementation on productivity of range ewes (Rambouillet and Columbia). Following breeding in November and December of each year, ewes were fed either no supplement or 0.33 pounds daily of an 11, 19, 29 or 36% protein supplement from January through late March. Following removal from winter range, ewes were fed grass hay and their respective pellet until about 10 days before lambing. During these 10 days, all ewes received alfalfa hay and 0.5 pounds of pellets. The range consisted of 4,200 acres approximately five miles from Livingston, MT. In general, the study area was gently to steeply rolling and offered sheep little shelter from winter wind. Most of the range was in good to excellent condition. Vegetation was mostly grass with a few forbs, shrubs and scattered trees on some ridge tops. The degree of use of grasses and fringed sagewort was determined during the winter of 1951-52. Percentage use represented the preference shown by sheep for the different species available. However, the diet of sheep was also affected by the abundance of species. In this study, bluebunch wheatgrass was not the most preferred species, but because of its abundance it was the most important species in the diet. Sheep use was 87% for sandberg bluegrass, although it only comprised 0.2% of the diet while junegrass and bluebunch wheatgrass use were 43.9 and 27.9% and comprised 33.4 and 36.0% of the diet, respectively. Range forage provided about 25% of the digestible protein requirement according to the National Research Council. However, they indicated that computed digestible protein intake was probably lower than actual intake. Van Horn et al. (1959a) found that increasing the protein content of supplements fed to ewes grazing winter range increased ewe weight gain (Table 5); however, average dollar return per ewe minus supplement costs was highest for ewes fed the 11% protein supplement ($51.00), and lowest for non-supplemented ewes ($45.90). It appears that when non-supplemented ewes lost less than five pounds of body weight during the winter, an energy supplement was satisfactory and no benefit was seen by feeding additional protein.

A second series of experiments were conducted from 1952 to 1955 to determine the influence of different winter feed supplements on range ewe production (Van Horn et al., 1959b). Approximately 1,000 ewes were put on the feeding trial in December of 1952 and 800 more in the next two years. Ewes were grazed on a leased ranch near White Sulfur Springs, MT, from mid-December to mid-March. Winter feed treatments are summarized in Table 6. Ewes were fed alfalfa

Table 5. Influence of protein supplementation on ewe weight change and lamb production.[a]

Supplement	Body weight change, pounds[b]	Lamb production per ewe, pounds	Grease fleece weight, pounds[b]	Value of lamb and wool minus supplement costs[c]
None	-4.4	59.9	10.0	45.9
11% protein	1.5	71.6	10.3	51.0
19% protein	4.3	65.3	10.3	46.8
28% protein	6.2	70.3	10.2	49.3
36% protein	8.2	70.0	10.3	49.2

[a] Van Horn et al. (1959a).
[b] Treatments were different ($P < 0.05$).
[c] Assumes supplements fed for 100 days at 0.33 pounds per head daily, grease wool value was $1.00 per pound and lamb value was $0.60 per pound. Costs of supplements used were: $132.00, $154.00, $194.00 and $215.00 per ton for 11, 19, 28 and 36% crude protein, respectively.

Table 6. Winter feed treatments, Montana range ewes, energy level trials, 1952 to 1955.[a]

Group	Amount of supplement: 1st half of winter	Amount of supplement: 2nd half of winter	Kind of supplement: 1st half of winter	Kind of supplement: 2nd half of winter	Roughage
0	None	None	None	None	Range forage
1	0.33 pounds all winter		11% protein pellet		Range forage
2	0.33 pounds all winter		Alfalfa pellet, 15 to 18% protein		Range forage
3	0.33 pounds	0.66 pounds	11% protein	30% protein	Range forage
4	0.66 pound	0.33 pound	30% protein	11% protein	Range forage
5	0.66 pound all winter		30% protein pellet		Hay
6	0.66 pound all winter		30% protein pellet		Range forage

[a] Van Horn et al. (1959b).

hay and 0.5 pounds of a 20% protein pellet beginning 10 days prior to the start of lambing. Results of these experiments are reported in Table 7. Ewes gained or lost body weight in direct proportion to the quantity of feed offered. Non-supplemented ewes lost 6.7 pounds, while the highest gain was by ewes fed hay and supplement (27.9 pounds). Grease fleece weights were higher for supplemented ewes compared to non-supplemented ewes. All ewes that were maintained on winter range and were supplemented weaned more pounds of lamb and had greater dollar return than non-supplemented ewes with the most profitable treatment being the ewes that received 0.33 pounds during the first half of the winter and 0.66 pounds during the second half of the winter (Group 3). It was more profitable to maintain ewes on winter range than in drylot with alfalfa hay and supplement.

Animal protein sources such as blood meal and feather meal are not as extensively degraded in the rumen of sheep compared to plant protein sources such as soybean meal (Hoaglund et al., 1992). This may be advantageous when protein requirements in the rumen are satisfied and additional protein is required to maximize genetic potential (Thomas et al., 1993a). A study conducted by Thomas et al. (1992b) during the winter of 1990-91 determined the influence of either energy or protein supplementation on the production of pregnant ewes grazing winter range (Table 8). Following breeding in December, ewes were fed the following winter supplements: 1) no supplement; 2) 0.33 pounds of a barley supplement; 3) 0.33 pounds of a soybean meal supplement; 4) 0.33 pounds of a blood meal supplement; or 5) 0.33 pounds of a feather meal supplement. The barley supplement contained 12.7% crude protein, while the protein supplements were formulated to contain 22% crude protein and supplements were fed at a rate of 0.33 pounds daily to provide 0.07 pounds of crude protein. The protein supplements contained 28.4, 14.5 and 14.2% of either soybean meal, blood meal or feather meal, in a barley carrier. Ewes were in excellent body condition at the beginning of the winter and had an average body condition score of 3.6. Ewes were fed for 84 days beginning mid-December and ending mid-March before

Table 7. Influence of winter supplementation treatments on ewe productivity.[a]

Group[b]	Body weight change, pounds	Grease fleece weight,[c] pounds	Lamb production per ewe,[c] pounds	Value of lamb and wool minus feed costs[d]
0	-6.7	10.5	57.2	42.6
1	2.1	10.8	67.8	47.3
2	1.6	11.0	65.4	46.5
3	10.1	11.2	73.0	50.2
4	7.3	11.3	71.2	49.2
5	27.9	11.7	78.6	41.1
6	15.5	11.5	73.4	47.6

[a] Van Horn et al. (1959b).
[b] Group defined in Table 11.
[c] Treatments significant ($P < 0.01$).
[d] Assumes supplements fed for 90 days, value of lamb and wool was $0.60 and $1.00 per pound, respectively. Feed costs were: winter range, $.025 per day; alfalfa hay, $60.00 per ton; alfalfa pellets, $100.00 per ton; 11% protein pellet, $130.00 per ton; 30% protein pellet, $190.00 per ton.

Table 8. Effects of winter supplementation on body weight and condition score change and ewe productivity.[a]

Item	Supplement[b]				
	None	Barley	Soybean meal	Blood meal	Feather meal
Weight change, pounds[c]	-2.4	2.6	5.3	4.2	4.2
Condition score change[c]	-0.6	-0.3	-0.3	-0.4	-0.4
Grease fleece weight, pounds	9.5	9.7	9.9	10.3	9.9
Lamb production per ewe, pounds	73.8	79.8	76.9	81.5	77.6
Value of lamb and wool minus supplement costs[d]	$53.8	$55.8	$54.0	$56.9	$54.6

[a] Thomas et al. (1992b).
[b] Barley supplement contained 12.7% protein and provided 17 grams of CP. Soybean, blood meal and feather meal supplements contained approximately 21% protein and provided 30 grams of CP. Blood and feather meals provided approximately 50% of crude protein equivalent in their respective supplements.
[c] Treatment significant ($P < 0.05$).
[d] Supplements fed for 84 days, and value of lamb and wool used were $0.60 and $1.00 per pound, respectively. Costs of supplements used were $130.00, $150.00, $163.00 and $160.00 per ton for the barley, soybean meal, blood meal and feather meal supplements.

shearing. Following shearing ewes were removed from winter range and fed according to NRC (1985) requirements for mature ewes in late pregnancy.

Ewes not supplemented lost more body weight and condition than supplemented ewes (Table 8). Barley (energy)-supplemented ewes gained less body weight than protein-supplemented ewes and lost a similar amount of body condition (0.3 to 0.4 units of body condition). Ewes not supplemented weaned less pounds of lamb and a lower dollar return per ewe than supplemented ewes. However, when supplement costs were subtracted from the monetary value of lamb and wool produced, no advantage was found among energy and protein supplements. The researchers concluded that increased body weight gain does not always translate into increased economic returns when ewes are in good body condition entering the winter, forage availability is good, winter weather is mild and ewes are fed adequately in late pregnancy. These results agree with earlier work of Van Horn et al. (1959a).

A second series of winter trials were conducted at the Red Bluff Research Ranch from 1991 to 1993 (Thomas et al., 1993b). Supplements fed were: 1) no supplement (CON); 2) barley (BAR); 3) blood meal plus feather meal (BM+FM); and 4) feather meal plus blood meal plus urea (FM+BM+U). In addition, a corn supplement was included in 1991-92 and an alfalfa pellet in 1992-93. Both of these supplements were fed at 0.66 pounds on alternate days and the alfalfa pellet provided 0.06 pounds of protein daily. The BM+FM supplement contained 28.0% feather meal and 18.1% blood meal while the FM+BM+U supplement contained 25.3% feather meal, 6.8% blood meal and 3.5% urea. Barley was the carrier in the protein supplements. The barley supplement (energy) was fed at 0.66 pounds while the protein supplements were fed at 0.33 pounds with all supplements being fed on alternate days. The protein supplements were formulated to provide approximately 0.07 pounds of crude protein on a daily basis. This level of protein was selected because work by Harris et al. (1989) determined that ewes grazing winter range at the same site were deficient by approximately 0.07 pounds of protein. Daily supplement protein intakes were: BAR, 0.04 pounds; BM+FM, 0.07 pounds; and FM+BM+U, 0.07 pounds. The BAR supplement provided twice the energy of the protein supplements while the protein supplements provided twice the protein as the BAR supplement. Ewes entered the winter in good body condition with an average body condition score of 3.6 in December of 1991. Snow cover was minimal. Range condition was good and the range was open most of the winter. Forage protein content and forage intake estimates for 1991-92 were 7.1% protein and 1.6% of body weight, respectively (Tables 1 and 2; Soder, 1993). Non-supplemented ewes lost more body weight and condition during the winter (84 days) than supplemented ewes (Table 9). No differences in body weight change were detected among supplemented ewes. Lamb mortality was lower for ewes supplemented with blood meal and feather meal and therefore percentage and pounds of lamb weaned were greater for these treatment groups. Reduction in lamb mortality may have been due to improved placental development in those ewes fed the protein supplements. Poor placental development will result in low transfer capacity of nutrients and oxygen to the fetus and reduced survival potential. Lamb production by energy supplemented ewes was similar to non-supplemented ewes. The value of lamb and wool minus supplement costs were slightly lower for corn-supplemented ($56.00) and barley-supplemented ($54.10) ewes compared with non-supplemented ewes ($57.70), with protein-supplemented ewes being greater than control. Therefore, only the protein supplements were cost effective when compared to the non-supplemented or energy-supplemented ewes. These data agree with

Table 9. Influence of energy or protein supplementation on body weight and condition score change and production of ewes grazing winter range, 1991-92.[a]

Item	Supplement				
	None	Corn	Barley	BM+FM[b]	BM+FM+U[c]
Body weight change, pounds[d]	-4.0	3.3	2.6	3.7	4.6
Condition score change[d]	-0.7	-0.3	-0.3	-0.4	-0.4
Grease fleece weight, pounds	9.2	9.7	9.5	9.2	9.5
Lamb weaned, %	115.4	116.5	112.3	122.9	125.9
Lamb weaned, pounds	80.9	80.2	77.3	84.6	86.7
Value of lamb and wool minus supplement costs[e]	57.7	56.0	54.1	58.6	60.3

[a] Thomas et al. (1993b). Data from 550 Targhee and Columbia range ewes.
[b] BM+FM = feather meal plus blood meal.
[c] BM+FM+U = feather meal plus blood meal plus urea.
[d] Treatment significant ($P < 0.05$).
[e] Supplements fed for 84 days, and value of lamb and wool used were $0.60 and $1.00 per pound, respectively. Corn and barley supplements fed at 0.33 pounds daily and cost $130.00 per ton. Protein supplements (FM+BM; FM+BM+U) were fed at 0.16 pounds daily and cost $200.00 and $170.00 per ton, respectively.

the early work of Clanton (1957) who reported improved lamb production by ewes fed a protein supplement during the winter compared to non-supplemented or corn-supplemented ewes.

In 1992-93, ewes entered the winter in good body condition (3.4) but winter weather was more severe than either 1990-91 or 1991-92. Snow cover reduced grazing time and subsequent forage availability. Forage protein content was 4.5% (Table 1) and estimated forage intake was 1.3% of body weight (Table 2; Soder 1993). Calculated protein intake would only be 30 to 40% of NRC (1985) requirements. Therefore, a gross protein deficiency was present. Ewes not supplemented lost more body weight and condition than energy- or protein-supplemented ewes (-12 pounds) while barley and alfalfa pellet treatments were intermediate (-6 pounds) to BM+FM and FM+BM+U (Table 10; Bohn et al., 1994). Lambs weaned per ewe starting the experiment were lowest for non-supplemented ewes and highest for the BM+FM treatment. The value of lamb and wool minus supplement costs were $13.20, $7.30, $6.20, $1.60 greater for BM+FM, alfalfa pellets, FM+BM+U and barley compared to non-supplemented ewes. Lamb mortality from birth to weaning of lambs born (dead or alive) was lower for supplemented ewes compared with ewes that were not supplemented. Although not shown in Table 10, lamb birth weights were 0.5 pounds heavier for those born to ewes supplemented with BM+FM+U compared to non-supplemented ewes. The alfalfa pellet treatment provided approximately 0.02 pounds more protein per day than the barley supplement and only slightly less energy (0.26 vs. 0.20 pounds of TDN). In summary, an energy supplement fed at 0.33 pounds daily was not as cost effective as a protein supplement fed at 0.16 pounds.

Conclusions

The experiments reviewed in this paper evaluated the influence of supplementation programs during mid-pregnancy on ewe productivity. Following breeding, ewes were maintained on winter range during the first 100 to 120 days of pregnancy. Inadequate ewe nutrition during mid-pregnancy can impede the growth and development of the placenta, which results in low transfer capacity of nutrients and oxygen to the fetus. If nutrient restriction during mid-pregnancy is severe enough, it can not be made up for in late pregnancy. Therefore, adequate nutrition in late pregnancy is wasted if good placental development has not occurred during mid-pregnancy. General conclusions are:

1. Supplementation is cost effective most winters in Montana.
2. Supplements fed at 0.25 to 0.33 pounds per head daily, or 0.2 to 0.3% of ewe body weight, did not reduce forage intake (Harris et al., 1989; Soder 1993), and environmental factors influenced forage intake more than supplement type (Soder, 1993).
3. Body condition entering the winter influences ewe productivity and the response to supplementation (Darroch et al., 1950). Ewes can lose some body condition (0.3 to 0.4 units of a body condition score) during the winter if they enter the winter in good body condition (Thomas et al., 1992b, 1993b; Bohn et al., 1994).
4. Ewes can be supplemented on alternate days while grazing winter range (Thomas et al., 1992a).
5. Energy supplements are cost effective when ewes can afford to lose some body weight, range forage is available and winter weather is mild (Van Horn et al., 1959a, 1959b; Thomas et al., 1992b).
6. Protein supplements are cost effective when ewes can not afford to lose body weight and need to gain weight (Darroch et al., 1950) or when winter weather reduces forage intake (Thomas et al., 1993b; Bohn et al., 1994). Protein supplements should provide a minimum of 0.07 pounds of crude protein intake daily.
7. Non-rumen degradable protein sources (feather meal, blood meal) are satisfactory sources of supplemental protein compared to soybean meal (Thomas et al., 1992b) and alfalfa pellets (Bohn et al., 1994). Due to the design of these studies, it would be difficult

Table 10. Effects of supplementation on ewe weight change and lamb production, 1992-93.[a]

Item	Supplement				
	None	Barley	Alfalfa pellets	BM+FM[b]	BM+FM+U[c]
Body weight change, pounds[d]	-12.3	-6.2	-5.5	1.5	-2.4
Condition score change[d]	-0.6	-0.4	-0.4	-0.3	-0.3
Grease fleece weight, pounds	8.6	8.4	8.4	8.4	8.6
Lamb weaned, %	100.1	102.7	116.3	118.6	113.3
Lamb weaned, pounds	72.3	78.2	87.0	92.3	84.5
Value of lamb and wool minus supplement costs[e]	51.9	53.5	59.2	65.1	58.1

[a] Data represents 540 ewe observations (Bohn et al., 1994).
[b] BM+FM = blood meal plus feather meal.
[c] BM+FM+U = blood meal plus feather meal plus urea.
[d] Treatment significant ($P < 0.05$).
[e] Values for lamb, wool and feed supplements similar to that reported in Table 9. Alfalfa pellets fed at 0.33 pounds daily and cost $100.00 per ton.

to recommend them over more conventional protein supplements. However, they could be substituted for them if they were less expensive per unit of protein. Also, more precautions must be taken when designing supplements using these protein sources since more problems with palatability can occur.

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A Review of Thiamin Requirement and Deficiency of Sheep and Goats[1]

K. Qi[2] and J.E. Huston[2,3]

Summary

This paper is a review of thiamin requirements and etiology of thiamin deficiency in sheep and goats. First, thiamin functions in carbohydrate metabolism and nerve impulse transmission were summarized. Second, requirements and factors affecting deficiencies of thiamin in sheep and goats were outlined. Third, specific symptoms of thiamin deficiency were described for both metabolic and nervous system disorders. Cerebrocortical necrosis (CCN) and polioencephalomalacia (PEM) refer to nervous system disorders in Europe and the United States, respectively. Fourth, new developments in laboratory diagnosis of thiamin deficiency and methods of treatments were reviewed.

Key words: thiamin, requirement, deficiency, diagnosis, sheep, goat.

Introduction

Thiamin (vitamin B_1) as thiamin pyrophosphate (TPP) is an important component (prosthetic group) of several enzymes including transketolase (EC 2.2.1.1), pyruvate decarboxylase (EC 4.1.1.1), pyruvate dehydrogenase (EC 1.2.4.1) and oxoglutarate dehydrogenase (EC 1.2.4.2; Gubler, 1984; Rammell and Hill, 1986; Page et al., 1989). These enzymes have the common feature that they catalyze the transfer of an activated aldehyde unit, which requires magnesium as a cofactor (Zieve, 1969). As a consequence of carbohydrate metabolism, thiamin deficiency leads to increased blood lactate, pyruvate and oxoglutarate levels. Thiamin function in the nervous system is poorly understood, but it seems to have a specific role independent of its coenzyme function. Possible mechanisms of action of thiamin in nerve tissue include the following: 1) thiamin is involved in the synthesis of acetylcholine, which transmits neural impulses; 2) thiamin participates in the passive transport of sodium in excitable membranes, which is important for the transmission of impulses at the membrane of ganglionic cells; and 3) thiamin, in its role in the activity of transketolase in the pentose phosphate pathway, is necessary for the synthesis of fatty acids and the metabolism of energy in the nervous system (Tanphaichitr, 1976; McDowell, 1989).

This paper reviews research on the thiamin requirements of sheep and goats, dietary and environmental factors causing thiamin deficiency and signs of thiamin deficiency in sheep and goats. Newly-developed methodologies in preventing, diagnosing and treating thiamin deficiency also are summarized.

Review of Literature

Thiamin Requirements of Sheep and Goats

Animals do not synthesize thiamin and thus must obtain this vitamin from their diet or, in the case of ruminants, from microbial synthesis in the rumen (Edwin and Jackman, 1982; National Research Council [NRC], 1981, 1985; Dougherty et al., 1991). Coprophagy, which is observed occasionally in sheep and goats (Huston, 1994), may help to supply the required thiamin because feces contains large amounts of microbiologically synthesized thiamin (Nakajima, 1984). Thiamin and its naturally occurring phosphate esters are water-soluble, causing their metabolic half-life to be relatively short. Although the principal storage organ appears to be the liver (Dancy et al., 1984), about half of the total thiamin in the body is contained within muscle tissue (Tanphaichitr, 1976).

The daily requirement for thiamin varies according to animal age, metabolic activity, feed intake and dietary

[1] Approved by the Director of the Texas Agricultural Experiment Station as TA-31565.

[2] Texas Agricultural Experiment Station, Texas A&M University System, San Angelo, TX 76901.

[3] To whom correspondence should be addressed.

composition. Requirements are increased during pregnancy and lactation, and when the carbohydrate content of the diet is high. The daily requirement of adult sheep has been estimated at 2 to 4 mg per day (Naga et al., 1975), which is similar to estimates of 1 to 3.5 mg per day for intraruminal synthesis of thiamin by sheep and cattle (Breves et al., 1980; Grigat and Mathison, 1982). This implies that unless there are significant amounts of thiamin in forage or other feeds, sheep and goats often may be on the borderline of thiamin deficiency. Thiamin requirements for animals are probably best expressed on an energy basis as in the case for humans where the recommended daily allowance of thiamin is 0.5 mg per 100 kcal or 0.6 mg per 100 kcal for pregnant or lactating women as mentioned by Read and Harrington (1981). If a maximum daily energy requirement is 4,800 kcal as in the case for a 75-kg ewe bearing twins in late pregnancy (Robinson, 1984), the theoretical requirement for sheep would be 2.9 mg per day. This confirms the experimentally derived estimate of daily requirement of 2 to 4 mg per day and suggests that requirements for other animals can be calculated on a similar basis.

Factors Causing Thiamin Deficiency in Sheep and Goats

Thiamin is present in herbage at low levels (7 mg per kg) and is chemically unstable (Gubler, 1984; Dougherty et al., 1991); thus the dietary supply of thiamin to grazing animals is limited. Thiamin adequacy in grazing ruminants is maintained by *de novo* thiamin synthesis by symbiotic rumen microorganisms. Thiamin deficiencies occur in sheep and goats when ruminal synthesis is interrupted by the changes in the diet that upset the rumen environment, when dietary nutrients are unbalanced and especially low in protein (Abe, 1969) or when thiamin is hydrolyzed by thiaminases produced by microorganisms in the rumen (Soita and Brent, 1993). Thiaminases were first demonstrated in the rumen of affected sheep and cattle in 1968 (Edwin and Jackman, 1973) but are often present without any overt signs of thiamin deficiency (Grigat and Mathison, 1983). A complex balance exists between thiamin production and its destruction by the ruminal microbial population. Feeding high-concentrate diets to sheep and goats changes the ruminal environment toward more thiamin destruction (Losada et al., 1971).

Some bacteria and fungi which contaminate feeds have been shown to produce thiaminases and may destroy thiamin in formulated diets before they are fed to animals. These thiaminase-producing bacteria and fungi coexist with some pasture plants such as fern species and are thought to pose a real threat to the well-being of animals grazing these plants in Australia (Wang, 1987; McDowell, 1989). It was demonstrated in cattle that alkaloids in ingested endophyte-infected tall fescue induced thiamin deficiency that could be cured by thiamin supplementation (Dougherty et al., 1991; Eng and Dougherty, 1991). Thiamin in vitamin supplements may be only 40% available (Zinn et al., 1987). Also, naturally produced analogs of thiamin may inhibit the function of enzymes which normally use TPP as a cofactor and therefore induce some clinical manifestations of thiamin deficiency (Spicer and Horton, 1981). It is well established that a thiamin deficiency is more likely in ruminants fed high-concentrate diets because these diets increase thiamin requirements for metabolism and change the ruminal ecosystem toward thiamin destruction (Lusby, 1971; Mella et al., 1976).

Signs of Thiamin Deficiency in Sheep and Goats

The clinical signs of thiamin deficiency may be divided into those attributable to general metabolic disorders and those related to disorders of the central nervous system, which are called polioencephalomalacia (PEM) in the United States and cerebrocortical necrosis (CCN) in Europe (Edwin and Jackman, 1973, 1974; Markson, 1980).

Metabolic Disorders. Clinical signs of metabolic disorders include profuse but transient diarrhea (Edwin and Jackman, 1973; Spicer and Horton, 1981), reduced growth rates or weight loss and anorexia (Nakajima, 1984). The diarrhea may be misdiagnosed as internal parasitism (Spicer and Horton, 1981), whereas the weight loss may be erroneously attributed to a variety of causes. There is considerable evidence of such weight loss throughout the world. Thiamin deficiency has been observed on Texas ranches (Menzies, 1994) and is considered to cause production losses in lambs (McDonald, 1982), weaned sheep (Spicer and Horton, 1981; Thomas and Griffiths, 1981) and cattle (Grigat and Mathison, 1982, 1983). The presence of ruminal thiaminases in many clinically normal sheep suggests that subclinical thiamin deficiencies may exist (Spicer and Horton, 1981). Significant differences in sheep body weight (BW) gain have been related to fecal thiaminase activity (Thomas, 1981). Sheep deprived experimentally of thiamin or given thiamin analogs show significant weight loss (Spicer and Horton, 1981). Naga et al. (1975) studied the changes in ruminal fermentation under thiamin deficiency and found that ruminal butyric acid concentration increased significantly, mainly at the expense of propionic acid formation.

Cipriano et al. (1987) found that thiamin deficiency affected the morphometric and cell proliferation of jejunum epithelium cells in rats and suggested that it is because transketolase and pyruvate decarboxylase are involved in the supply of the vital precursors such as ribose and adenosine triphosphate (ATP) for nucleotide synthesis. These enzymes are very important in maintaining tissue integrity, especially in tissue with great cell proliferation. The intestinal epithelium showed a significantly decreased villus length and depth and lowered cell population of the crypt in thiamin-deficient rats compared to rats receiving adequate thiamin. Alopecia (hair loss) in thiamin-deficient sheep and goats might be related to thiamin function in maintaining skin integrity as indicated by the findings of Cipriano et al. (1987).

Polioencephalomalacia (PEM). Clinical signs of PEM are more clearly recognized than those of metabolic disorders but are manifested at a later stage of thiamin deficiency. Animals placed on a thiamin-deficient diet may show no clinical signs of PEM for three to five weeks or longer (Thornber et al., 1979) despite the fact that blood thiamin levels rapidly fall and metabolic signs appear. This delay may be explained by differences in the role of thiamin in the nerve excitation processes (Dreyfus, 1965; Tanphaichitr, 1976) or by differences in the apoenzyme-thiamin complexes in the brain which buffer this tissue against sudden and marked decreases in enzyme activity. Dreyfus (1965) found that transketolase (TK) levels fell much faster in the blood than in the brain when a thiamin deficiency was imposed, suggesting that brain thiamin remains relatively stable except during severe depletion. Irreversible pathological changes are thought to occur only when brain TK levels fall below 50% and brain thiamin levels fall below 20% of normal (Dreyfus, 1965).

Polioencephalomalacia associated with thiamin deficiency has been reported most commonly in sheep, cattle and dogs, although it also occurs in goats, horses, deer (Merck Veterinary Manual, 1979; Edwin and Jackman, 1973; Grigat and Mathison, 1983; Lusby, 1971; Doran and Owens, 1987) and other species. Typical signs of PEM are summarized in Table 1. If treated early, animals respond to large intravenous doses of thiamin. If treatment is delayed, survivors may be permanently blind or may suffer permanent central nervous system impairment (Doran and Owens, 1987). The only visible PEM lesions are those in the gray matter of the cerebral cortex where multiple foci of necrosis of the neurones occur and many of the cerebral gyri are swollen (Edwin and Jackman, 1973, 1974; Lusby, 1971). A transverse section of the affected brain shows, under long ultraviolet illumination, a typical blue-green fluorescence under the meninges in the outer cortex that may be used as a diagnostic aid for PEM (Jackman, 1985).

Outbreaks of PEM are sporadic. Reported morbidity rates in sheep and cattle vary but are generally less than 10% of populations (Gabbedy and Richards, 1977). Mortality rates in affected animals often approach 100% (Merck Veterinary Manual, 1979; Edwin and Jackman, 1974). Animals of all ages are susceptible to PEM, but the young appear to be most vulnerable (Edwin and Lewis, 1971). There appears to be a seasonal trend with sheep, goats and cattle that may be associated with higher metabolic demands for thiamin caused by pregnancy, lactation and decreased thiamin availability in the pasture. Feeding high concentrate diets to ruminants may induce PEM and disturb this seasonal pattern (Lusby, 1971; Doran and Owens, 1987).

There is little doubt that some field cases of PEM result from a progressive thiamin deficiency induced by the action of bacterial thiaminases in the gut and rumen (Edwin and Jackman, 1982) or by ingested plant thiaminases (Edwin and Jackman, 1974; McDowell, 1989). Lusby (1971) studied the effects of bacterial thiaminases in sheep and found that when a liquid diet containing the energy equivalent of 150% of maintenance was infused into the rumen, PEM developed if the diet did not contain thiamin. In comparison, sheep which received 150 mg per day of thiamin from the liquid diet did not develop deficiency symptoms. Lusby (1971) suggested that rumen bacteria were the source of thiaminases causing the thiamin deficiency. Because the animals received only the semi-purified liquid diet, no extraneous plant or animal source of thiaminase or thiamin antimetabolite was possible. However, the precise roles of thiaminases have been difficult to establish because ruminal (and fecal) thiaminases are often present without any overt signs of PEM (Grigat and Mathison, 1982). The complex balance between thiamin production and thiamin destruction in the rumen depends upon the changing microbial population. Polioencephalomalacia presumably occurs when the long-term rate of destruction exceeds the rate of production thereby depleting body reserves of thiamin. Normal body reserves are sufficient for only about three weeks before PEM ensues (Thomas, 1981).

Doran and Owens (1987) suggested that elevated sulfate from gypsum, dynamate or other sources increased ruminal thiamin destruction so that thiamin deficiency and PEM occurred in cattle. Sadler et al. (1983) also studied the relationship between sulfate and PEM in cattle with 30% roughage diet adding 0.72% sulfate from $MgKSO_4$ and found that this level of inorganic sulfate could cause PEM in cattle. A sulfate level of 0.72% is equivalent to 0.365% sulfur which is below the toxicity level for cattle (NRC, 1980). Unfortunately, the authors failed to give the basal sulfur content of the diet. Gooneratne et al. (1989) reported the biochemical changes in sulfate-induced PEM in sheep. They fed sheep a barley, soybean meal and alfalfa-based diet containing 0.63% sulfur (S) by adding sulfate with or without thiamin supplementation (13.7 mg per kg dry matter [DM] in the diet). Sheep supplemented with thiamin remained normal, whereas sheep without thiamin supplementation developed PEM. They speculated that PEM may be caused by a direct, toxic effect of sulfur, sulfur metabolites or thiamin antimetabolites in the brain rather

Table 1. Clinical signs of polioencephalomalacia.[a]

Dullness	Standing precariously
Aimless wandering	Blindness
Circling	Opisthotonos
Unsteadiness	Hyperaesthesia
Incoordination	Nystagmus
Staggering	Clinic extensor spasms
Trismus	Lateral recumbency
Convulsions	Coma

[a] Summarized from Lusby (1971); Edwin and Jackman (1973); Grigat and Mathison (1983); Jackman (1985); Doran and Owens (1987).

than by a thiamin deficiency *per se.* Leichter and Joslyn (1969) reported that sulfites could destroy thiamin in aqueous solutions. However, McDowell (1989) suggested that sulfates could increase the stability of thiamin in the formulated diet at storage. The relationship of thiamin nutrition and sulfate related to PEM deserves further study.

New Developments in Diagnosing Thiamin Deficiency

The most widely accepted approach to evaluate thiamin status of animals and humans is the *in vitro* stimulating effect of thiamin pyrophosphate (TPP) on erythrocyte transketolase activity (ETKA; Jackman, 1985; Grandal and Torp-Pedersen, 1985; Rammell and Hill, 1986). The increase of ETKA after stimulation (ETKAS) with TPP (measured as a percentage increase) is called the thiamin pyrophosphate effect (TPPE). Jackman (1985) gave an index for using percentage of TPP effect as a diagnostic method for sheep and cattle (Table 2). However, use of percentage of the TPP effect is not accurate. Grandal and Torp-Pedersen (1985) suggested an evaluation method of thiamin nutrition on the basis of three indexes: ETKA, ETKAS and TPPE (Table 3).

A systematic diagnostic method was given by Jackman (1985) which includes: 1) diagnosis in the live animal for subclinical thiamin deficiency; 2) diagnosis in the live animal for clinical thiamin deficiency; and 3) postmortem examination.

McDowell (1989) concluded that PEM diagnosis is conclusive when the following four situations exist:

1. *Case history:* animals have been maintained on high-energy feeds rich in carbohydrates, and other animals on the same farm have, from time to time, died after exhibiting nervous system disorders.
2. *Biochemical evidence:* blood pyruvate concentration has increased radically and the activity of erythrocyte-transketolase has been reduced.
3. *Diagnostic therapy:* animals thought to be suffering from PEM react promptly to treatment with thiamin, provided they are treated in the early stages of the disease.
4. *Pathological changes:* necropsy shows typical pathological anatomical changes – bilateral cortical necrosis – in the brain.

Treatment Methodology for Thiamin Deficiency

Successful treatment of thiamin deficiency depends upon early recognition of the disease when animals may respond rapidly, often within a few hours, to a single dose of thiamin (Spicer and Horton, 1981; Eng, 1993). Recommendations for treatment of PEM with thiamin vary from 100 to 500 mg for sheep and goats, 200 to 500 mg for calves and 1,000 to 2,000 mg for cattle depending on body weight (Jackman, 1985), usually administrated by intramuscular injection. A dose of thiamin at 2 to 4 mg per kg BW is probably sufficient for all species in which thiamin deficiency is diagnosed or suspected (Merck Veterinary Manual, 1979; Rammell and Hill, 1986).

Much of the thiamin that is administered therapeutically is rapidly excreted. Thiamin hydrochloride (300 mg) given intravenously to cattle was almost totally excreted within 24 hours, and blood thiamin levels returned to pre-injection levels within three hours (Nakajima, 1984). Therefore, thiamin injections two to four times a day for one to two days have been recommended for treatment of PEM (Merck Veterinary Manual, 1979). However, excretion rates can be decreased by using thiamin derivatives such as propyldisulfide (TPD) or tetrahydrofurfuryl disulfide (TTFD) that are less water-soluble. With TTFD, only about 50% of the thiamin is excreted within 24 hours (Nakajima, 1984). Other advantages of TPD and TTFD are

Table 2. Enzymatic activity of erythrocyte transketolase (percent thiamin pyrophosphate effect and range) for polioencephalomalacia diagnosis.[a]

Species	PEM[b]	No PEM[b]	PEM[b], treated with thiamin
Cattle			
Average	172	33	34
Range	120-247	17-67	3-431
Sheep			
Average	122	23	40
Range	96-158	12-41	13-118

[a] Adapted from Jackman (1985).
[b] PEM = polioencephalomalacia.

Table 3. A hypothetical model of the changes of ETKA, ETKAS and TPPE in progressing thiamin deficiency.[a]

ETKA[b]	ETKAS[c]	TPPE[d]	Thiamin nutrition
Normal	Normal	Normal	Normal
Normal	Raised	Raised	Marginal deficiency
Low	Normal	Raised	Marginal to moderate deficiency
Low	Low	Raised	Moderate to severe deficiency
Low	Low	Normal	Factors other than thiamin deficiency play a role

[a] Adapted from Grandal and Torp-Pedersen (1985).
[b] ETKA = the changes of erythrocyte transketolase activity.
[c] ETKAS = the ETKA stimulated *in vitro* with thiamin pyrophosphate (TPP).
[d] TPPE = the percentage increase of ETKA after stimulation with thiamin pyrophosphate (TPP) *in vitro*, called the thiamin pyrophosphate effect.

that they are absorbed rapidly from the gut and are not destroyed by thiaminases (Edwin and Jackman, 1974). Therefore, TPD or TTFD can be given to sheep and goats as a prophylactic treatment under field conditions.

Conclusions

Thiamin plays important roles in carbohydrate metabolism and nervous system functions. Sheep and goats can not synthesize thiamin in their bodies and rely on dietary supply and microbial synthesis in the gastrointestinal tract. Therefore, during pregnancy and lactation and/or when dietary carbohydrate contents are high, such as in a feedlot situation, sheep and goats often may be on the borderline of thiamin deficiency. Thiaminases produced by ruminal microorganisms, and by certain strains of bacteria and fungi which contaminate the feed ingredients, destroy thiamin and induce a thiamin deficiency in sheep and goats. The signs of thiamin deficiency commonly are categorized into metabolic disorders and central nervous system disorders; the latter are best known as PEM in the United States Newly-developed laboratory methodologies for diagnosis and treatment for thiamin deficiency are available to assist scientists and producers in preventing, recognizing and treating thiamin deficiencies.

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Effects of Immunocastration on Growth, Carcass Characteristics and Reproductive Development in Ram Lambs

D.A. Daley[1,2], T.E. Adams[3], C.A. Daley[3], W.R. Patton[1] and J.L. Evans[1]

Summary

Thirty fall-born Polypay ram lambs were allotted by birth date to one of three treatment groups in a study designed to evaluate the effect of immunoneutralization of gonadotropin-releasing hormone (GnRH) on reproductive development, growth and carcass characteristics. Treatments were: 1) intact ram lambs (n=10); 2) intact ram lambs immunized against GnRH (n=10); and 3) surgically castrated ram lambs (n=10). Lambs were castrated or immunized at 30 days of age, and all lambs were weaned at an average age of 60 days and placed on a growing diet in an elevated lamb feeding facility. Antibodies against GnRH were detected in all immunized lambs within eight weeks after immunization. Anti-GnRH antibody titers were maximal 16 weeks after immunization. Treatment did not affect ($P > 0.05$) growth, carcass weight or loin eye area. Immunization increased dressing percentage ($P < 0.05$), compared to intact and physically castrated lambs. Immunization produced carcasses that were intermediate to the castrated and intact carcasses in fattening patterns as reflected by carcass characteristics such as backfat thickness, kidney/pelvic fat and Yield Grade. Immunization reduced ($P < 0.01$) serum concentrations of testosterone (0.3 ng/ml), scrotal circumference (18 cm) and mean testicular weight (22.5 g) compared to intact controls (1.4 ng/ml, 28.3 cm and 212.5 g, respectively). These data indicate that immunization against GnRH is an effective alternative to physical castration in lamb production.

Key words: immunization, GnRH, ram lambs, testes, testosterone, growth.

Introduction

Physical removal of the testes is a traditional management technique for the production of meat animals. Castration renders a more acceptable product for consumers and produces a less aggressive, more easily managed animal. Concerns over the invasive nature of physical castration have lead to the search for effective alternatives that are less traumatic to the animals. Several investigators have examined the effects of "immunocastration" as a non-invasive alternative to physical castration in management of livestock. One approach involves active immunization against gonadotropin-releasing hormone (GnRH), the hypothalamic peptide that controls gonadal growth, development and function. Antibodies against GnRH would be expected to bind GnRH as it is released from the hypothalamus, thus preventing the release of luteinizing hormone (LH) from the pituitary gland. Luteinizing hormone is the positive regulator of testosterone secretion from the testes. Inhibition of LH secretion reduces testicular function and development.

Attempts to adapt this procedure to domestic livestock have produced conflicting results. Schanbacher (1982) reported that immunocastrated rams had reduced growth performance and feed conversion efficiency when compared to control rams or surgically castrated lambs. In addition, backfat of immunocastrated rams was more similar to the control rams in these studies. Conversely, immunocastrated cattle had superior growth performance to steers, with carcass composition intermediate between that of surgically castrated cattle and bulls (Robertson et al., 1982; Adams et al., 1993).

Typically, GnRH must be conjugated to a carrier protein to enhance immunogenicity. In addition, immunocastration protocols generally require multiple injections of the

[1] School of Agriculture, California State University, Chico, CA 95929.

[2] To whom reprint requests should be addressed.

[3] Department of Animal Science, University of California, Davis, CA 95616.

GnRH-carrier protein conjugate to produce an antibody titer sufficient to block GnRH action. Keyhole limpet hemocyanin (KLH) was the protein selected for conjugation to GnRH in this study. The GnRH-KLH conjugate has been shown to be effective in sheep (Adams and Adams, 1986).

This study was conducted to evaluate the effect of a single immunization with the GnRH-KLH conjugate in ram lambs on GnRH antibody titer, reproductive development, post-weaning growth (measured as average daily gain in the feedlot) and carcass characteristics.

Materials and Methods

Fall-born Polypay ram lambs averaging 16.8 kg body weight were allotted by birth date to one of three treatments at 30 days of age. The treatments were: 1) intact ram lambs (INT, n=10); 2) intact ram lambs immunized against GnRH (IMM, n=10); and 3) surgically castrated ram lambs (SC, n=10). All lambs were weaned at 60 days of age and placed on an elevated screen floor feeding facility with 3.7 m of bunk space provided per treatment group. Lambs were fed a pelleted growing diet of alfalfa hay (46%), almond hulls (13.7%), whole corn (15.3%), wheat (15.3%), cottonseed meal (8.2%), salt (1%), oyster shell flour (0.31%), ammonium chloride (0.26%) and decox (0.017%) available *ad libitum*. Weight and scrotal circumference were recorded at 28-day intervals. Blood samples were collected by jugular venipuncture at 28-day intervals for determination of serum testosterone (T) and anti-GnRH titer concentrations.

Lambs were slaughtered 16 weeks after immunization (average age = 5 months) at the USDA-inspected Meats Laboratory at California State University, Chico, CA. Carcasses were evaluated 24 hours post mortem according to standard USDA methodology for lamb grading (Boggs and Merkel, 1990). Testes from the INT- and IMM-treated lambs were collected at slaughter for determination of total testis mass and sperm concentration. Sperm concentrations were evaluated using a modification of the procedure of Amann and Lambiase (1969). One to two grams of testicular tissue were homogenized in 10 mL of saline containing 0.01% merthiolate using a Brinkmann homogenizer (Brinkmann Instruments, Westbury, NY). The homogenate was diluted 1:5 with saline, and the number of elongated spermatid nuclei was determined using a hemocytometer and phase-contrast microscope.

Immunization Procedures

Synthetic GnRH (U.S. Biochemical, Cleveland, OH) was conjugated to KLH (Calbiochem, San Diego, CA) according to the procedure detailed previously (Adams and Adams, 1986; 1990). Lambs in the immunized group received 1.0 units of the GnRH-KLH conjugate (0.65 mg of GnRH covalently linked to 1.0 mg of KLH) in a 2-ml emulsion consisting of equal volumes of saline and Freund's complete adjuvant. The emulsion was injected subcutaneously on the dorsal aspect of the neck. Lambs did not receive a secondary immunization (i.e., booster).

Determination of Testosterone and Anti-Gonadotropin-Releasing Hormone Titer

Serum concentrations of testosterone were determined by radioimmunoassay as described previously (Adams et al., 1987). The intra- and interassay coefficients of variation for all assays were less than 10%. Serum anti-GnRH titers were determined as described by Adams and Adams (1986). The anti-GnRH titer is expressed as the percentage of total $[^{125}I]$ GnRH that was bound to antibody in a 1:1,000 dilution of serum.

Statistical Analyses

Data were analyzed with standard one-way analyses of variance, and when significant treatment effects were detected, mean comparisons were made with Duncan's multiple range test (Gill, 1978). One lamb from the surgically castrated group died from urinary calculi during the feedlot phase of the trial. Data from that lamb were not included in the analyses.

Results and Discussion

All lambs immunized against GnRH developed anti-GnRH titers (33.8 ± 18.6%) within eight weeks of immunization (Table 1). Peak titer (52.4 ± 15.2%) was recorded at the time of slaughter, 16 weeks post immunization. Antibody titer against GnRH was not detectable in unimmunized lambs. Serum concentrations of testosterone were suppressed ($P < 0.01$) in IMM lambs compared to INT rams, thus illustrating the inverse relationship between anti-GnRH titer and serum testosterone concentration. Serum testosterone concentration in the IMM group (0.3 ng/mL) did not

Table 1. Antibody titers and testicular characteristics for unimmunized intact ram lambs and ram lambs actively immunized against GnRH (anti-GnRH).[a]

Treatment	N	Anti-GnRH titer, % (1:1,000)[b]	Testes weight, g	Sperm, 10^6/g	Testosterone, ng/ml	Scrotal Circum., cm
Ram Lamb	10	–	212.5 ± 54.8	48.6 ± 27.2	1.4 ± 0.53	28.3 ± 3.6
Anti-GnRH	10	52.4 ± 9.6	22.5 ± 10.9	0.0	0.3 ± 0.37	18.0 ±- 1.9
P-value			< 0.01		< 0.01	< 0.01

[a] Treated lambs were immunized against GnRH at 30 days of age and all lambs were slaughtered at an average age of five months.
[b] The ANTI-GnRH titer is presented as a percentage of the total $[^{125}I]$GnRH bound by 0.1 mL of a 1:1,000 dilution of serum.

differ ($P > 0.05$) from that in the SC group (0.1 ng/mL). While the reduction in total serum testosterone was significant, the immunization procedure did not completely inhibit endogenous testosterone production.

Active immunization against GnRH also reduced scrotal circumference and testes weights relative to the INT rams. In addition, the testes of immunized rams were completely devoid of spermatozoa. These data are consistent with the response to active immunization in other domestic animals. In boars and bulls, immunization against GnRH decreased LH secretion and reduced testicular size, testosterone secretion and spermatogenesis (Grizzle et al., 1987; Adams et al., 1993).

In contrast to the study of Schanbacher (1982), no treatment differences ($P > 0.05$) in final live weight, average daily gain, carcass weight or loin eye area were detected during the 111-day experimental period (Table 2). However, SC and INT treatments affected ($P < 0.01$) backfat thickness (0.43 vs. 0.23 cm); IMM lambs were intermediate (0.3 cm) and not different from either the SC or INT lambs (Table 3). The IMM lambs were intermediate to the SC and INT lambs in their fattening patterns and overall carcass characteristics. The IMM lambs were leaner than the SC and fatter than INT lambs as reflected in kidney-pelvic fat, backfat thickness and Yield Grade. The IMM lambs were not different from SC lambs ($P > 0.05$) in kidney-pelvic fat (3.0 vs. 3.2%) or Yield Grade (2.6 vs. 3.0). However, the IMM and SC lambs were fatter than the INT ram lambs, based on kidney-pelvic fat ($P < 0.05$) and Yield Grade ($P < 0.01$). These data are consistent with previous studies that indicate that intact rams yield leaner carcasses and lower dressing percentages than do wethers (Schanbacher et al., 1980; Glimp, 1971). This leaner condition has been attributed to testicular production of testosterone, which redirects metabolism toward enhanced protein deposition and bone growth. Castrated males reach physiological maturity at lighter weights than their intact contemporaries and therefore begin to deposit fat at a younger age. (Klosterman et al., 1976; Oltjen, 1982).

Total carcass weights did not differ among treatment groups in the present study, perhaps because of the young age at which these lambs were slaughtered. Had the feeding period been extended beyond 111 days, differences in total weight and carcass product might have been more evident. Also, this early slaughter date may have negated some additional negative effects in the INT lambs such as prominent neck and shoulder muscles known as "bucky". This condition reduces the carcass quality and is attributed to testicular testosterone.

The dressing percentage for IMM lambs was greater than that for INI or SC lambs. These differences may be attributed to the increased fatness of the IMM compared to the INT lambs, and the slight advantage in muscularity of the IMM compared to the SC lambs.

Table 2. Growth and carcass weight of unimmunized wethers and ram lambs and ram lambs actively immunized against GnRH (anti-GnRH).[a]

Treatment	N	Initial weight, kg	Final weight, kg	Carcass weight, kg	Dressing percent
Wether	9	16.4 ± 3.9	44.9 ± 6.6	22.6 ± 3.6	50.3^{b} ± 2.5
Ram Lamb	10	16.2 ± 2.4	48.1 ± 6.9	24.1 ± 4.0	50.1^{b} ± 1.6
Anti-GnRH	10	17.8 ± 3.2	47.3 ± 4.9	24.7 ± 2.5	52.4^{c} ± 1.4
P-value		> 0.05	> 0.05	> 0.05	< 0.05

[a] Treated lambs were immunized against GnRH at 30 days of age and all lambs were slaughtered at an average age of five months.
[b,c] Means with different superscripts differ ($P < 0.05$).

Table 3. Carcass traits of unimmunized wethers and ram lambs and ram lambs actively immunized against GnRH (anti-GnRH).[a]

Treatment	N	Backfat thickness, cm	Kidney pelvic fat, cm	Loin eye area, cm^2	Yield Grade
Wether	9	0.4^{b} ± 0.07	3.2^{b} ± 0.4	5.8 ± 0.6	3.0^{c} ± 0.6
Ram Lamb	10	0.2^{b} ± 0.02	2.3^{c} ± 0.6	6.1 ± 0.5	2.2^{b} ± 0.3
Anti-GnRH	10	0.3^{bc} ± 0.04	3.0^{b} ± 0.5	6.4 ± 0.5	2.6^{bc} ± 0.3
P-value		< 0.01	< 0.05	> 0.05	< 0.01

[a] Treated lambs were immunized against GnRH at 30 days of age and all lambs were slaughtered at an average age of five months.
[b,c] Means with different superscripts differ ($P < 0.05$).

Conclusions

The results of this study indicate that a single immunization with GnRH-KLH conjugate suppresses testicular growth and development in young ram lambs. Additionally, the immunization procedure seems to produce a commercially acceptable lamb carcass that is intermediate to the SCC and INT carcasses. Thus active immunization against gonadotropin-releasing hormone could become a non-invasive alternative to surgical castration in lamb production systems.

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Effects of Prepartum Doe Dietary Protein and Energy Intake on Performance and Blood Characteristics of Precolostral Alpine Kids[1,2]

M. Smuts[3] and T. Sahlu[3,4]

Summary

The objectives of this experiment were to determine the effect of maternal nutrition on neonate performance and to determine whether prepartum maternal nutrition influences precolostral neonatal plasma characteristics. In the first of two experiments, 44 primiparous Alpine does were offered either 8.8, 11.0 or 14.3% crude protein (CP) on a dry matter (DM) basis in an isocaloric (2.06 Mcal metabolizable energy [ME] per kilogram DM) diet. In the second experiment, 63 multiparous Alpine does were offered either 8.4, 11.4 or 14.4% CP and 1.8, 2.2 or 2.6 Mcal ME per kilogram DM *ad libitum* starting in week 12 of gestation. Jugular blood samples, collected from kids within the first 15 minutes after birth, were analyzed for various metabolites. In experiment 1, total protein ($P < 0.05$), and in both experiments plasma urea nitrogen (N; $P < 0.0001$), were higher in neonates born to does fed diets with 14.3% protein. Free fatty acids (FFA), packed cell volume and ammonia N in experiment 1, and glucose, total protein, FFA and creatinine in experiment 2, were unaffected by maternal nutrition. In the first experiment, glucose was depressed at intermediary CP levels, but neonatal birth weight (BW) did not differ between treatments, whereas neonatal BW was increased ($P < 0.05$) at intermediary CP and energy levels in the second experiment. In both experiments, FFA concentrations were two to four times higher in neonatal than maternal blood. It is speculated that the high FFA concentrations encountered may be due to very rapid (less than 15 minutes after birth) mobilization of adipose tissues by the neonate or because the goat may contain higher concentrations of lipoprotein lipase (which facilitates the hydrolysis of maternal triglycerides to FFA and transfer of these FFA to the fetus) in the placental tissues than other species. This factor needs further investigation. Calculations indicate that the effect of nutrition on performance characteristics should be assessed preferably using individual neonate BW or its metabolic unit instead of litter weight or its metabolic unit. It is concluded that goat maternal dietary CP variations affect neonatal plasma characteristics to a greater extent than maternal dietary energy and that current CP recommendations for goats are adequate for neonatal survivability.

Key words: neonate, dietary energy, dietary protein, pregnancy, Alpine.

Introduction

Late pregnancy is by far the most nutritionally demanding period of pregnancy as it pertains to neonatal survival and growth. When nutrition is not a limiting factor, fetal mass increases in a curvilinear manner with the fetus gaining 85, 50 and 25% of its final BW in the last 8, 4 and 2 weeks of gestation (Robinson, 1982). According to Hinch et al. (1985), much of the variation in lamb survival is due to BW. The optimum survival is achieved at intermediate BW, because dystocia is a problem with heavy

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[3] E (Kika) de la Garza Institute for Goat Research, Langston University, Langston, OK 73050.

[4] To whom correspondence should be addressed: P.O. Box 730, Langston University, Langston, OK 73050; voice phone (405) 466-3836, fax (405) 466-3138.

lambs at birth, whereas starvation is a problem with light lambs.

The energy and protein requirements of the ruminant fetus are met by placental transport of glucose and amino acids from maternal to fetal circulations (Bell, 1993). Fetal placental gluconeogenesis may compensate for nutritional shortages (Rattray, 1992) but is considered a relatively less important process in the fetus (Bell, 1993). The amount of glucose available to the fetus depends on the concentration of glucose in the maternal blood, because placental glucose transport occurs by facilitated diffusion and is dependent on the maternal-fetal plasma concentration gradient. Furthermore, previous authors (Sahlu et al., 1992, 1995) have shown that pre-partum nutrition affects the blood characteristics of does after parturition. The objectives of this experiment were to determine the effect of maternal nutrition on litter weight and kid performance and to determine whether prepartum maternal nutrition influences the precolostral plasma characteristics of Alpine kids.

Materials and Methods

In the first of two separate experiments, 44 primiparous Alpine does (48 ± 1.2 kg body weight) from the experiment of Sahlu et al. (1992), were blocked by body weight in week 12 of gestation and assigned randomly to one of three dietary treatments: 1) 8.8% CP; 2) 11.0% CP; and 3) 14.3% CP on a dry matter (DM) basis (Table 1). All diets were fed to parturition and were isocaloric (2.06 ± 0.03 Mcal ME/kg DM) and fed *ad libitum* to ensure 10% orts. In the second experiment, 63 multiparous Alpine does (52.9 ± 2.5 kg body weight) from the experiment of Sahlu et al. (1995) were blocked by body weight and number of fetuses (detected by ultrasonography) on day 90 of gestation and assigned randomly to one of nine dietary treatments (Table 2). The treatment design was a three-by-three factorial arrangement, using three levels of crude protein (8.4, 11.4 and 14.4% CP; DM basis) and three levels of energy (1.8, 2.2 and 2.6 Mcal ME/kg DM). The median levels were at the National Research Council (NRC) requirements for gestating goats (NRC, 1981). Does were fed their respective diets until parturition for *ad libitum* intake with 10% orts. The effects of protein level (Sahlu et al., 1992) and energy and protein level (Sahlu et al., 1995) on performance of does were reported previously.

In both experiments, does were placed in individual maternity pens one week prior to expected parturition and monitored. Immediately after birth, each neonate was tagged, sexed and weighed. A sample of jugular blood was collected from the kids by venipuncture within 15 minutes after birth. Blood sample tubes were immediately chilled in an ice bath, transported to the laboratory and centrifuged at 1,500g at 4 °C for 20 minutes. Aliquots of plasma were stored at -20 °C until analyzed. Packed cell volume (PCV) was determined with a microhematocrit centrifuge. Plasma glucose was analyzed colorimetrically by the glucose-oxidase procedure of Gochman and Schmitz (1972) using a Technicon Autoanalyzer II system (Technicon Instruments, Tarrytown, NY). Total protein concentration was measured using a Sigma total protein diagnostic kit (Sigma Diagnostics, St. Louis, MO). Plasma FFA were determined using a commercial kit (Wako Chemicals, Richmond, VA). Plasma creatinine was analyzed colorimetrically using Sigma Kit #555-A (Sigma Diagnostics, St. Louis, MO). Plasma ammonia and urea were analyzed using a Technicon Autoanalyzer II system (Technicon Instruments, Tarrytown, NY) according to the method of Chaney and Marbach (1962).

The data were analyzed using the general linear models procedure of SAS (1989). To remove the confounding effect of litter size from the analysis, plasma variables glucose, FFA and urea N were used to determine the most appropriate covariate by best fit procedures. Neonate performance indices were calculated and expressed in various forms including: litter size, litter weight, litter weight$^{0.75}$, neonate BW, neonate BW$^{0.75}$, litter weight$^{0.75}$ divided by litter size (an estimate of neonate BW$^{0.75}$), litter weight divided by litter size (an estimate of neonate BW) and neonate BW$^{0.75}$ multiplied by litter size (an estimate of litter weight$^{0.75}$) and tested by regression analysis for best fit. Based on this analysis, litter weight$^{0.75}$ divided by

Table 1. Composition of diets (experiment 1).

	Crude Protein, %		
Item	8.8	11.0	14.3
Ingredients (% of DM):			
Ground corn	30.0	22.0	16.8
Cottonseed hulls	56.8	44.8	51.0
Soybean meal	1.0	2.0	11.0
Alfalfa hay, chopped	10.0	30.0	20.0
Trace-mineralized salts[a]	1.0	1.0	1.0
Dicalcium phosphate	1.0	–	–
Vitamin ADE premix[b]	0.2	0.2	0.2
Nutrients, DM basis:			
DM, %	87.9	91.4	91.5
CP, %	8.8	11.0	14.3
ADF, %	37.2	34.1	34.6
GE, Mcal/kg[c]	4.47	4.34	4.33
ME, Mcal/kg[d]	2.10	2.05	2.04

[a] Containing (%) NaCl 94 to 95; Mn > 0.2; ferrous Fe > 0.16; ferric Fe > 0.14; Cu > 0.033; Zn > 0.10; I > 0.007; Co > 0.005.
[b] Each gram contained 2,200 IU of vitamin A, 2,200 IU of vitamin D and 0.2 IU of vitamin E.
[c] Gross energy.
[d] Calculated ME (NRC, 1981).

litter size was identified as the most appropriate covariate (see Results and Discussion). In experiment 1, CP effects were determined by linear and quadratic regression using litter $weight^{0.75}$ divided by litter size as a covariate. In experiment 2, the effects of CP and energy levels and their interactions on kid performance and plasma characteristics were tested by regression analysis using litter $weight^{0.75}$ divided by litter size as a covariate.

Results and Discussion

Litter size and nutrition.

Litter size has a confounding effect on BW and several plasma characteristics, as illustrated in Table 3. Performance variables such as litter weight are higher for twins and triplets, whereas the BW of single neonates were higher than the BW of twins or triplets. Also, plasma characteristics such as glucose and total protein were affected by the number of kids per litter. Thus it would be erroneous to use litter size as a covariate when determining differences due to CP or energy levels because of the effect of litter size on BW and the effect of BW on plasma characteristics. In experiment 1, the plasma variables glucose, FFA and urea N were used to determine the most appropriate covariate to remove the confounding effect of litter size from further analyses. These variables best described litter $weight^{0.75}$ divided by litter size (an estimate of neonate $BW^{0.75}$) with $R^2 = 0.21$ ($P < 0.08$). These same variables described neonate $BW^{0.75}$ ($R^2 = 0.20$; $P < 0.09$), litter size ($R^2 = 0.19$; $P < 0.09$), litter weight ($R^2 = 0.09$; $P < 0.41$), litter weight divided by litter size ($R^2 = 0.20$; $P < 0.08$), neonate BW ($R^2 = 0.20$; $P < 0.09$) and litter $weight^{0.75}$ ($R^2 = 0.10$; $P < 0.37$). In experiment 2, this tendency was repeated. The same plasma variables described litter $weight^{0.75}$ divided by litter size ($R^2 = 0.21$; $P < 0.006$), but neonate $BW^{0.75}$ ($R^2 = 0.12$; $P < 0.09$), and litter size ($R^2 = 0.09$; $P < 0.19$), litter weight ($R^2 = 0.04$; $P < 0.58$), litter $weight^{0.75}$ ($R^2 = 0.04$; $P < 0.56$), litter weight divided by litter size ($R^2 = 0.13$; $P < 0.06$) and neonate $BW^{0.75}$ ($R^2 = 0.12$; $P < 0.09$). These analyses show that indices such as litter weight and litter size may not be clear indicators of nutritional variations as mirrored by changes in plasma characteristics of neonates. Indices of individual neonate BW (in this case litter $weight^{0.75}$ divided by litter size) provide a clearer reflection of treatment effects (as shown by the highest R^2) and for this reason was used as a covariate in further statistical analyses. The selection of this factor, as apposed to indices of litter weight, may be due to the effect of kid BW on plasma characteristics, which depend on the degree of undernutrition or the number of fetuses carried (Rattray, 1992). However, litter weight (because it is affected by litter size) is more indicative of genetic potential.

Performance and plasma characteristics.

Neonate performance and neonatal plasma characteristics for experiments 1 and 2 using litter $weight^{0.75}$ divided by litter size as a covariate are shown in Tables 4 and 5, respectively. In experiment 1, concentrations of plasma total protein and urea N were higher in neonates born to does fed higher protein levels. These two effects were also observed in the

Table 2. Composition of diets (experiment 2).

	Crude Protein, %								
	8.4			11.4			14.4		
	ME, Mcal/kg DM			ME, Mcal/kg DM			ME, Mcal/kg DM		
	1.8	2.2	2.6	1.8	2.2	2.6	1.8	2.2	2.6
Ingredient (% of DM):									
Ground corn	15.0	40.0	55.0	6.25	24.7	53.2	2.4	20.0	43.0
Cottonseed hulls	72.9	53.0	24.0	73.0	45.0	29.0	78.0	50.0	27.0
Soybean meal	3.0	1.0	0	10.5	9.2	6.8	17.8	16.4	14.5
Dried molasses	8.0	5.0	20.0	9.45	20.0	10.0	1.0	12.0	14.5
Trace-mineralized salt[a]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
$CaCO_3$	0.10	0.50	0.50	0.30	0.30	0.50	0.50	0.30	0.50
Dicalcium phosphate	0.50	0.0	0.0	0.0	0.30	0.0	0.0	0.0	0.0
Vitamin ADE premix[b]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Nutrients, DM basis:									
DM, %	91.1	90.5	90.9	91.3	91.5	90.4	91.0	90.3	90.8
CP, %	8.43	8.45	8.39	11.4	11.4	11.4	14.6	14.4	14.4
NDF, %	67.8	51.7	27.8	68.3	45.2	32.4	73.0	49.8	31.1
ADF, %	54.3	40.2	20.0	54.9	35.5	23.8	58.8	39.2	23.0
ME[c]	1.84	2.19	2.56	1.84	2.22	2.56	1.82	2.18	2.56

[a] Contained 98.8% NaCl, 7.2 ppm Cu, 5.4 ppm Co, 21 ppm Fe, 24.0 ppm Mn, 21.6 ppm Zn, 10.2 ppm I.
[b] Added to provide 1000, 100 and 10 IU of vitamin A, D, and E, respectively, per kilogram diet.
[c] Calculated ME (NRC, 1981).

maternal plasma (Sahlu et al., 1992). Plasma urea N concentrations were higher in neonatal than in maternal blood, as measured by Sahlu et al. (1992). This is considered the norm (Faulkner, 1983) because the fetal liver produces large amounts of urea, which is readily transported across the placenta and excreted by the ewe (Bell, 1993). Plasma proteins and urea N are sensitive to nutritional influences (Kaneko, 1989). However, decreases in plasma proteins may be indicative of nitrogen loss and increased protein turnover caused by temperature stress. Temperature stress will often cause mobilization of adipose tissues to FFA and glycerol (Kaneko, 1989). Neonates from the lowest CP treatment had slightly lower BW ($P > 0.10$) than the neonates from the higher CP treatments and their FFA concentrations were slightly higher ($P > 0.10$). It may be that the neonates with lower BW experienced a mild hypothermia. Lambs with higher BW are more resistant to hypo- and hyperthermia because they have a lower surface area-to-volume ratio, higher summit metabolism per unit surface area, higher energy reserves of body lipid and glycogen and also more of the critically important thermogenic brown adipose tissue than smaller lambs from undernourished ewes (Rattray, 1992).

Plasma glucose concentrations of neonates born to does fed the intermediary CP (11%) concentration were much lower than those measured by Sahlu et al. (1992) in the maternal plasma, and the depression in glucose concentration at the intermediary protein concentration was not observed in the maternal plasma. Overall, neonatal plasma glucose concentrations were lower than maternal plasma concentrations found by Sahlu et al. (1992). Fetal blood glucose concentrations are always lower than maternal concentrations (Daniels et al., 1974; Girard et al., 1979); this ensures that the maternal-fetal plasma glucose concentration gradient is maintained, allowing the facilitated diffusion of glucose to occur. However, protein concentration had no effect on glucose concentrations in maternal plasma (Sahlu et al., 1992). In piglets, hypoglycemia (glucose < 40 mg/dL) is the cause of many neonatal mortalities (Kaneko, 1989; Newcomb et al., 1991). At birth, piglet blood glucose is greater than 110 mg/dL but then drops within 24 to 36 hours. This is not necessarily the case with lambs, calves

Table 3. Effect of litter size on neonate performance variables and plasma characteristics.

Item	Litter size				
	Singles	Twins	Triplets	SE[a]	P <
Experiment 1:					
Litter weight, kg	4.83[b]	8.08[c]	10.00[d]	0.32	0.0001
Litter weight$^{0.75}$	3.26[b]	4.79[c]	5.62[d]	0.14	0.0001
Neonate BW[e], kg	4.83[b]	4.04[c]	3.33[d]	0.25	0.01
Neonate BW$^{0.75}$	3.26[b]	2.85[c]	2.47[d]	0.13	0.01
Litter weight/litter size, kg	4.83[b]	4.04[c]	3.33[d]	0.16	0.0001
Litter weight$^{0.75}$/litter size	3.26[b]	2.39[c]	1.87[d]	0.07	0.0001
Neonate BW$^{0.75}$ × litter size	3.26[b]	5.69[c]	7.40[d]	0.26	0.0001
PCV, n	46.30	45.10	39.80	2.60	NS[f]
Glucose, mg/dL	39.60[b]	31.7[b]	6.23[c]	8.70	0.06
Free fatty acids, mg/L	310.00	271.00	285.00	29.00	NS[f]
Total protein, mg/dL	39.00[b]	34.0[c]	36.00[d]	0.74	0.0001
Ammonia N, µg/dL	270.00	201.00	193.00	35.00	NS[f]
Urea N, mg/dL	13.10	10.20	12.10	1.40	NS[f]
Experiment 2:					
Litter weight, kg	3.89[b]	7.20[c]	10.10[d]	0.25	0.0001
Litter weight$^{0.75}$	2.77[b]	4.38[c]	5.67[d]	0.11	0.0001
Neonate BW, kg	3.89[b]	3.60[b,c]	3.37[c]	0.14	0.09
Neonate BW$^{0.75}$	2.77[b]	2.60[c]	2.48[c]	0.07	0.09
Litter weight/litter size, kg	3.89[b]	3.60[b,c]	3.37[c]	0.12	0.05
Litter weight$^{0.75}$/litter size	2.77[b]	2.19[c]	1.89[d]	0.06	0.0001
Neonate BW$^{0.75}$ × litter size	2.77[b]	5.21[c]	7.44[d]	0.16	0.0001
Glucose, mg/dL	55.40[b]	43.30[c]	42.70[c]	3.78	0.06
Free fatty acids, mg/dL	201.00	229.00	210.00	17.00	NS[f]
Total protein, mg/dL	41.10[b]	38.50[c]	39.30[c]	0.55	0.004
Creatinine, mg/dL	0.59	0.59	0.59	0.03	NS[f]
Urea N, mg/dL	12.40	12.50	10.60	1.68	NS[f]

[a] SE = standard error of the mean.
[b,c,d] Means within the same row that do not share a common superscript are different.
[e] BW = birth weight.
[f] NS = not statistically significant.

and foals which can resist starvation hypoglycemia for more than a week (Kaneko, 1989). Guyton (1981) states that the amount of glucose stored in the human neonate in the form of glycogen is sufficient to supply its needs for a few hours. This may also be the case in the neonates in this experiment. At birth, all the neonates in our two experiments had plasma glucose concentrations within the range that causes hypoglycemia in piglets. Plasma, however, was not sampled at a later stage of neonatal life, so it is assumed that this glucose concentration, albeit low, was maintained by the neonates. Daniels et al. (1974) also found very low plasma glucose concentrations (13 mg/dL) in lambs at birth and suggested that newborn neonatal ruminants (lambs and calves) may not be dependent upon glucose as their principal energy substrate during the first 24 hours of life. Hypoglycemia is characterized as impaired gluconeogenesis associated with a decrease in plasma FFA (Kaneko, 1989), which was not the case here. In fact, gluconeogenesis is considered a relatively unimportant process in the fetus (Daniels et al. 1974; Bell, 1993). Slight elevation ($P > 0.10$) of FFA was observed in neonates with lower BW compared to neonates with higher BW, suggesting that minimal fat mobilization was taking place in the neonates with lower BW.

The FFA concentrations measured in neonatal plasma were two to four times greater than the FFA concentrations of the does (range from 100 to 500 µM; Sahlu et al., 1992). This is in contrast to findings from the human, monkey, sheep, cow, horse and rat, where the concentration of FFA are always higher in maternal than in fetal plasma (Girard et al., 1979). Furthermore, FFA are generally very low in fetal plasma (Faulkner, 1983). Free fatty acids can cross the placenta, but only to a very limited extent (Bell, 1993) in certain species (rat, guinea pig, monkey, rabbit, sheep; Girard et al., 1979). However, lipoprotein lipase is an enzyme which has been found in the placenta of human, rabbit and rat and is capable of hydrolyzing triglycerides into FFA and glycerol (Girard et al., 1979; Faulkner, 1983). This suggests that the placenta has the capacity to extract FFA from circulating triglycerides and to transfer them to the fetus after hydrolysis by the lipoprotein lipase (Girard et al., 1979). In our experiment, it can be speculated that the high FFA concentrations observed in the neonates of this study may have been caused by two different actions. First, the high concentrations of neonatal FFA may have been due to mobilization from neonatal adipose tissues in response to reduced environmental temperatures and catecholamine release during birth (Faulkner, 1983). This reaction is known to occur within one hour after birth (Faulkner, 1983) but may have occurred within 15 minutes after birth in our experiment. Second, it may be possible that the goat has a greater capacity to transport placental FFA than measured in other species. This may be due to greater amounts of lipoprotein lipase in goat placental tissues. This irregularity in maternal-to-neonatal FFA ratio requires further investigation.

Protein concentration did not affect neonate $BW^{0.75}$ and other indices expressed in metabolic units or litter weight and neonate BW (Table 4). This is contrary to literature for sheep

Table 4. The effect of three levels of crude protein in doe rations on precolostral neonate performance variables and plasma characteristics using litter weight$^{0.75}$ divided by litter size as a covariate in experiment 1.

	Crude Protein, %				P <	
Item	8.80	11.0	14.3	SE[a]	L[b]	Q[c]
Does, n	14	15	15	–	–	–
Singles, n	3	1	3	–	–	–
Twins, n	16	26	18	–	–	–
Triplets, n	0	0	3	–	–	–
Litter weight, kg	7.96	8.07	8.10	0.34	0.61	0.87
Litter weight$^{0.75}$	4.73	4.79	4.78	0.16	0.68	0.84
Neonate BW[d], kg	3.98	4.04	4.04	0.17	0.92	0.88
Neonate $BW^{0.75}$	2.81	2.84	2.84	0.09	0.89	0.88
Neonate $BW^{0.75}$ × litter size	5.63	5.69	5.74	0.28	0.55	0.93
PCV, n	45.70	44.00	44.80	1.64	0.78	0.55
Glucose, mg/dL	38.80	18.80	32.80	5.21	0.78	0.006
Total protein, mg/dL	33.90	33.60	35.30	0.53	0.03	0.20
Free fatty acids, mg/dL	1,036.00	1,001.00	916.00	61.70	0.14	0.87
Urea N, mg/dL	7.42	11.10	11.90	0.71	0.0005	0.05
Ammonia, µg/dL	194.00	213.00	204.00	22.00	0.93	0.60

[a] SE = standard error of the mean.
[b] L = linear effect.
[c] Q = quadratic effect.
[d] BW = birth weight.

(Preston et al., 1965; Ressel et al., 1967a; Ressel et al., 1967b) in which prepartum energy and protein restriction has been reported to reduce neonate BW by 20 to 30%. Similarly, it has also been reported that the weight of the calf will be reduced under poor nutritional conditions in late pregnancy (Roy, 1980).

In experiment 2, concentrations of plasma urea N were higher in neonates born to does fed higher protein levels. Similar tendencies have been reported previously by Kaneko (1989) and Preston et al. (1961). Higher plasma urea N concentrations were also reported by Sahlu et al. (1995) in the plasma of does fed higher protein levels. At the first two CP levels, energy also seemed to increase plasma urea N concentrations, which is contrary to the effect of energy on urea N concentrations in the plasma of does (Sahlu et al., 1995). The level of CP had an effect on all indices of litter weight (litter weight, litter weight$^{0.75}$ and neonate $BW^{0.75}$ multiplied by litter size) whereas energy and the interaction of CP and energy had no effect. The interaction of the intermediary protein (11.4%) and intermediary energy (2.2 Mcal/kg DM) levels resulted in a higher neonate BW ($P > 0.10$). Although plasma total protein increased quadratically with energy concentration in doe plasma (Sahlu et al., 1995), a similar effect was not observed in neonatal plasma. Neither CP nor energy affected creatinine concentrations even though creatinine followed a similar pattern to urea in the study of Sahlu et al. (1995), unaffected by energy but affected by protein concentration.

Maternal dietary CP variations affected neonatal plasma characteristics and neonatal performance (Table 5) to a greater extent than maternal dietary energy. Faulkner (1983) stated that the ability of the mother to sustain the fetal body at the expense of her own body tissues is less in the case of protein deficiency than it is for energy deficiency. This may explain the tendency for neonatal plasma to mimic maternal dietary CP intake, whereas neonatal glucose and FFA show no correspondence with maternal energy intake, even though maternal plasma characteristics respond to dietary energy (Sahlu et al., 1995). It should be remembered that the median levels used in this experiment are, in fact, equivalent to the NRC requirements for gestating goats (NRC, 1981). These prescribed values are not only adequate, but quite possibly optimal, for ensuring neonatal hardiness.

Conclusions

The effect of nutrition on performance characteristics should be assessed using individual neonate birth weight or its metabolic unit instead of litter weight or its metabolic unit. The high FFA concentrations observed in neonatal plasma warrants further investigation. Maternal dietary CP variations affect neonatal plasma characteristics to a greater extent than maternal dietary energy. Current CP recommendations are adequate to ensure neonatal hardiness.

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Table 5. Neonatal performance and plasma metabolites of neonates born to does fed different prepartum crude protein and energy levels using litter weight$^{0.75}$ divided by litter size as a covariate in experiment 2.

	Crude protein, %												
	8.4			11.4			14.4						
	ME, Mcal/kg DM			ME, Mcal/kg DM			ME, Mcal/kg DM				P<		
	1.8	2.2	2.6	1.8	2.2	2.6	1.8	2.2	2.6	SE	CP	ME	CP×ME
Does, n	7	7	7	7	7	7	7	7	7	–	–	–	–
Singles, n	3	1	2	1	2	2	3	1	2	–	–	–	–
Twins, n	8	12	8	8	10	8	6	10	8	–	–	–	–
Triplets, n	0	0	3	6	0	3	3	3	3	–	–	–	–
Litter weight, kg	5.42	6.97	6.36	7.57	8.07	7.79	7.37	7.87	6.55	0.61	0.03	0.22	0.71
Litter weight$^{0.75}$	3.51	4.27	3.96	4.53	4.76	4.62	4.44	4.67	4.07	0.29	0.03	0.21	0.71
Neonate BW[a], kg	3.35	3.60	3.47	3.63	3.78	3.66	3.59	3.69	3.53	0.11	0.20	0.22	0.96
Neonate $BW^{0.75}$	2.47	2.61	2.53	2.62	2.69	2.64	2.61	2.66	2.57	0.19	0.22	0.28	0.96
Neonate $BW^{0.75}$ x litter size	3.99	5.05	4.67	5.51	5.75	5.63	5.37	5.67	4.77	0.44	0.03	0.31	0.68
Glucose, mg/dL	50.67	45.01	42.88	48.65	46.13	40.02	40.73	42.93	46.44	5.34	0.79	0.74	0.61
Total protein, mg/dL	38.66	40.06	39.59	38.40	39.03	38.73	39.15	38.58	38.25	0.79	0.38	0.83	0.71
Free fatty acids, mg/dL	684.89	916.13	608.29	781.24	822.15	851.23	852.15	730.64	883.34	79.70	0.36	0.85	0.06
Urea N, mg/dL	6.43	6.42	10.91	9.08	10.11	12.32	21.68	15.03	15.63	1.17	0.0001	0.015	0.0003
Creatinine, mg/dL	0.65	0.56	0.58	0.63	0.59	0.58	0.59	0.59	0.51	0.041	0.53	0.18	0.75

[a] BW = birth weight.

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Research Briefs

Pathologic and Serologic Responses of Isogeneic Twin Lambs to Phenotypically Distinct Lentiviruses

de la Concha-Bermejillo, S.J. Brodie, S. Magnus-Corral, R.A. Bowen and J.C. DeMartini

College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO
[Dr. de la Concha's present address: Department of Pathobiology, Texas A&M University Agricultural Experiment Station, 7887 N Highway 87, San Angelo, TX 76901.]

Cited from: J. Acquired Immuno Deficic. Syndr. Human. Retrovirol. 8:116–123. 1995

Ovine progressive pneumonia is a chronic debilitating disease of sheep caused by ovine lentivirus (OvLV), a nononcogenic, exogenous retrovirus. Lentiviral infection in sheep leads to a disease complex characterized by cachexia and chronic active inflammation in the lungs, lymph nodes, joints, mammary gland and the central nervous system (CNS). Clinical evidence of respiratory disease in OvLV-infected sheep includes dyspnea, progressive emaciation and development of opportunistic infections. Lentivirus-associated arthritis in sheep occurs naturally two to three years after infection and begins insidiously with weight loss and swelling of the carpal joints and bursae. Other joints are less frequently affected. Animals with OvLV-associated arthritis become lame and cachectic despite having good appetites. More than 63% of the ewes in OvLV-affected flocks may show evidence of inflammation of the mammary gland. Lesions tend to be diffuse and bilateral and consist of follicular lymphoid hyperplasia around lactiferous ducts, interstitial infiltration of mononuclear cells and fibrosis. Agalactia and poor lamb growth is a common sequela. Animals with severe CNS lesions will show signs of ascending paralysis – abnormal hind limb gait progressing to incoordination and hind limb paralysis over a period of weeks or months.

A large proportion of OvLV-infected sheep, however, never show any clinical signs of disease. It has been shown that the type and severity of the disease may be related to differences in OvLV strain variability. To rule out that these differences were due to differences in host genetic factors, genetically identical twins were artificially produced. Embryos in late morula or early blastocyst stages were split with a micromanipulator and the two demiembryos were transferred to the uterus of a recipient ewe. Newborn lambs were inoculated as follows: one lamb from each of three sets of identical twins was inoculated with a highly pathogenic strain of OvLV (85/34), and the corresponding twin was inoculated with an OvLV strain of low pathogenicity (84/28). One lamb of a fourth set of twins was inoculated with the pathogenic strain of OvLV and the corresponding twin was inoculated with a cell culture supernatant. The degree of lung inflammation (lymphoid interstitial pneumonia), as determined by histologic analysis of the lung sections collected at necropsy, was independent of the virus strain used for inoculation. The lack of difference in the degree of pulmonary inflammation between lambs with identical genetic background suggests that host genetic factors may be very important in determining which animals infected with OvLV manifest clinical disease.

– Prepared by A. de la Concha-Bermejillo.

Vitamin E and Selenium in Milk of Ewes

A. Meneses, T.R. Batra and M. Hidiroglou

Dept. de Analisis Clinicos, Escuela de Medicina Veterinaira, Universidad Nacional, Heredia, Costa Rica and Centre for Food Animal Research, Ottowa, Ontario, Canada.

Cited from: Canadian J. Anim. Sci. 74:567–569.

Newborn lambs have low levels of vitamin E and selenium (Se) because of the low rate of placental transfer of these elements. They are able to satisfy their needs at an early age by suckling colostrum, provided they receive colostrum which has an adequate concentration of these elements. The concentration of vitamin E in colostrum is higher than in milk. This study was undertaken to evaluate the effectiveness of injectable vitamin E and Se to ewes receiving recommended dietary levels of vitamin E and Se. Eighteen ewes were randomly assigned to one of three treatment groups of six ewes each. The treatments were: control; vitamin E (2,000 IU injected intramuscular) at lambing and at six weeks after lambing; and, 12 mg sodium selenite by intramulcuslar injection at lambing and at five weeks after lambing. Milk samples were collected at 0, 1, 2, 7, 14, 21, 28, 35, 42, 49 and 56 days post-lambing. The results indicated that injection of these elements increased the concentration of the respective element in the milk. In addition, the injection of Se tended to increase the concentration of vitamin E in milk, but not the reverse. Low levels of vitamin E in milk is more likely to be a problem for animals which have been fed harvested and stored feeds with no access to green forages. Problems with Se may more likely be specific to the area where the animals are produced or where the feedstuffs are grown.

– Prepared by Maurice Shelton.

News and Notes

Beginning with this issue, the SID Sheep and Goat Research Journal will contain a News and Notes section. This section will include short items of interest to subscribers and to the industries represented. Contributions of this nature are encouraged; selected and edited copies of this type of material will be published at no charge. Statements of positions available or prospective employees will be published for a nominal fee. For more information, contact Maurice Shelton at (915) 653-4576.

Position Announcement

The Department of Animal Science, University of Minnesota, invites applications for an Assistant Professor/ Sheep Scientist. This is a 12-month, tenure-track faculty position located at the West Central Experiment Station, Morris, MN, with tenure held in the Department of Animal Science, University of Minnesota, St. Paul, MN. Research will focus on sheep production with emphasis on sheep's role in sustainable agriculture systems, value added enterprises and economic competitiveness of sheep production systems. The appointee will be responsible for developing individual project leadership and multidisciplinary investigations which involve faculty at other University of Minnesota locations and neighboring states. Active participation in the Minnesota Extension Service's Sheep Focus Team, teaching an alternate year sheep production course and advising graduate students are expected. Requirements include a PhD with emphasis in animal science, documented research experience in livestock production and management, demonstrated written and oral communication skills and documented cooperation with co-workers. Send a letter of application that includes a statement of interests relevant to this position, vita and copies of all college transcripts, and have three letters of reference sent independently by April 15, 1995, to Dr. Lee Johnston, Chair, Animal Science Search Committee, c/o Susan Kubitschek, University of Minnesota, Department of Animal Science, 120 Peters Hall, 1404 Gortner Avenue, St. Paul, MN 55108; telephone: (612) 589-1711; fax: (612) 589-4870; e-mail: johnstlj@caa.mrs.umn.edu. The University of Minnesota is an equal opportunity employer and specifically invites and encourages applications from women and minorities.

Sheep Check-off Legislation

The Sheep Promotion, Research and Information Act of 1994 was passed by the 103rd Congress and signed by the president. The act enables legislation for the U.S. Sheep Industry to create a check-off program via referendum. In order to be implemented, a referendum must pass by a majority vote of sheep producers, feeders and importers or by two-thirds of the production represented by those voting. The referendum will likely be held in October, 1995, and call for an assessment of one cent per pound on live sheep or sheep product (live equivalent); two cents per pound on imported wool products (clean basis). The annual estimated assessments are approximately $13 million, including $7 million from domestic products and $5 million from imported products. The act calls for 20% of the domestic assessment to be returned to state associations proportional to their production.

–prepared by Paul Rodgers.

Sheep Industry Annual Convention – 1995

The 1995 Sheep Industry Annual Convention will be held in Washington, DC, February 7 to 11 at the Hyatt Capital Hill. Call (303) 771-3500 for information.

Selenium Supplementation Issue Settled

In an amendment to the Federal Crop Insurance Reform Act, the Food and Drug Administration (FDA) is not permitted to implement or enforce a stay on the 1987 amendments to the selenium food additive regulation unless the FDA commissioner can prove that Selenium supplementation at the levels established in the 1987 amendments:

1. is not essential to maintain animal health,
2. is not safe to animals consuming the additive or humans consuming edible portions of selenium-supplemented animals,
3. is not effective to promote normal growth and reproduction; and
4. cannot be reasonably controlled by the manufacturer and user.

The FDA's Center for Veterinary Medicine plans to take appropriate actions to clarify the situation and alleviate concerns resulting from the proposed "stay" on the 1987 amendments published in the September 1, 1993, Federal Register.

–prepared by Paul Rodgers.

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

In citing literature in the text, use both authors if there are only two. If there are more than two, use the first author and et al. Authors are asked to provide "interpretive summaries" for use by the sheep and goat industries in other media.

Proofing
Primary authors will receive galley proofs of articles. Corrected proofs should be returned by the deadline indicated. Failure to do so will result in delay of article publication.

Reprints
Fifty reprints of each article will be provided at no cost to the primary author. When galley proofs are sent, the author will be requested to complete a reprint order form requesting free and any additional reprints and provide the name of the institution, agency or individual responsible for the reprint charges.

Charge
The publication charge for the Sheep & Goat Research Journal is $60.00 per page. Contributors will be billed following publication. All manuscripts and correspondence should be addressed to the Sheep & Goat Research Journal, 6911 South Yosemite Street, Englewood, CO 80112-1414, unless noted otherwise on materials received from the editorial staff.

Sheep & Goat
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Volume 11, Number 2: 1995

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Editorial Review Board

American Sheep Industry Association

6911 South Yosemite Street
Englewood, CO 80112-1414
Phone (303) 771-3500
Fax (303) 771-8200

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Contents:

American Sheep Industry Association

Seasonality in Budgeted Lamb Feeding Returns

Clement E. Ward[1]

Summary

Research has identified a seasonal pattern in budgeted cattle feeding returns, actual cattle feeding returns and budgeted hog finishing returns. Seasonal input prices for feeder lambs and seasonal output prices for slaughter lambs suggest that lamb feeding returns also exhibit a seasonal pattern. Two independently developed budgets for lamb feeding were used in this analysis, one by the American Sheep Industry Association and the other by Oklahoma State University. Budgeted lamb feeding returns also exhibit a seasonal pattern. On average, budgeted lamb feeding returns were highest for lambs placed on feed in January and marketed at the end of March or early April and lowest for lambs placed on feed in April and marketed at the end of June or early July. Which budget was used affected the level of returns but not the seasonal pattern of returns. Lamb feeders need to understand the seasonality of feeder lamb prices, slaughter lamb prices and estimated lamb feeding returns. Such information should be useful in deciding when to place lambs on feed, when to market lambs and whether animals should be pushed or held back during the feeding period.

Key words: lambs, feeding, costs and returns, seasonality, prices.

Introduction

Research has identified a seasonal pattern in budgeted cattle feeding and hog finishing profits (Bliss and Ward, 1989b; Ward, et al., 1989).[2] Seasonal patterns in returns relate in large part to seasonality in input prices (feeder livestock, grain) and seasonality in output prices (slaughter livestock prices; Bliss and Ward, 1989a). Differences were found between budgeted cattle feeding returns and actual returns in cattle feeding, based on an analysis of feedlot closeout sheets (Trapp and Ward, 1990). However, differences were in level of returns, not in the seasonal patterns which emerged from alternative data sources and analyses.

In lamb feeding, seasonal input prices for feeder lambs and seasonal output prices for slaughter lambs suggest that lamb feeding returns may also exhibit a seasonal pattern. Several factors affect cattle feeding, hog finishing and lamb feeding returns besides seasonal input and output prices. Those factors were not captured explicitly in analyses of budgeted cattle feeding and hog finishing returns, though for cattle feeding they were implicitly captured when analyzing actual returns. Regardless, seasonality in input and output prices swamped effects from animal performance variability (Trapp and Ward, 1990).

This article deals primarily with the effects from seasonal feeder and slaughter lamb prices on lamb feeding returns. Impacts from varying animal performance assumptions are not addressed explicitly. However, the procedure followed enables implicitly examining potential variability in lamb feeding returns due to marketing earlier or later than expected because of varying animal performance.

Materials and Methods

Enterprise budgets are site-specific so using a budget for anywhere except a specific feedlot operation may be perceived as a limitation. For that reason, two independently developed budgets were used in this analysis and the results from each compared. No judgment was made as to whether one budget was better than the other. One lamb feeding budget was compiled by the American Sheep Industry Association (ASI; Grauberger, 1994) and the other was developed at Oklahoma State University (OSU) for lamb feeding in Oklahoma.

Budgets varied in the weight of lambs placed on feed, weight of lambs sold for slaughter and other budgeted items (Table 1). Thus, inherent

[1] Professor and Extension Economist, Department of Agricultural Economics, Oklahoma State University, Stillwater, OK 74078.

[2] Profits refer to returns over variable costs. Therefore, returns are used in this article rather than profits.

animal performance assumptions also varied. Cash operating expenses differed for feed, buildings and equipment, animal health, marketing and other expenses. However, total cash operating expense differences, excluding the cost of feeder lambs, were relatively small ($21.20 per head for budget 1 from ASI; $22.66 per head for budget 2 from OSU).

Lamb feeding budgets used in this analysis were calculated repeatedly with monthly average prices for feeder lambs and slaughter lambs from January 1979 to April 1994. Monthly average prices are essentially mid-month prices. Lambs were assumed to be on feed about 75 days. Thus, assuming feeder lambs are placed on feed at mid-month for 75 days, they would be marketed at the end of one month or the beginning of the next. Therefore, budgets were calculated with market price dates for two months and three months, thus implying 60-day and 90-day feeding periods, respectively. For example, feeder lambs placed on feed January 15 for 75 days would be marketed at the end of March or the beginning of April. Therefore, slaughter lamb prices for March 15 (60 days) and April 15 (90 days) were used. The shorter period can be thought of as earlier-than-expected marketing due to better-than-expected animal performance, while the longer period can be thought of as later-than-expected marketing due to worse-than-expected animal performance.

Budgeted returns were analyzed with Statistical Analysis System (SAS) software. Differences in returns from the two budgets along with within-year and between-year differences in returns were analyzed and seasonal return indexes computed for the most recent five-year and ten-year periods.

Results and Discussion

Seasonal Feeder Lamb Prices

A seasonal price index defines the average price level for an agricultural commodity in relation to an annual average price. Figure 1 shows monthly price indexes for feeder lambs at San Angelo, TX, over the most recent five-year and ten-year periods (1989-93 and 1984-93, respectively).[3] San Angelo is one of the few markets for which monthly average prices are readily available (Economic Research Service) to compute seasonal price indexes. A monthly index of 100 means the monthly average price has historically equaled the annual average price. When monthly price indexes exceed 100 and the curved line in Figure 1 lies above the horizontal line equaling 100%, then prices in those months have historically been above the annual average price. For example, a monthly price index of 109.3 (March, the last ten years), means the monthly average price over the past ten years was 9.3% above the annual average price (109.3 minus 100).

Conversely for price indexes below 100, when the curved line lies below the horizontal line equaling 100%, then prices in those months have historically been below the annual average price. So a monthly price index of 92.2 (July, the last ten years), means the monthly average price over

Table 1. Lamb feeding budgets.

Budget 1	Per head	Per pound
Income:		
Slaughter lambs ($66.50/cwt; average weight: 125 lb)	83.13	0.67
Total income	**83.13**	**0.67**
Costs:		
Purchase (84-lb feeder lambs; $69.00/cwt)	57.96	0.46
Feed (31.9¢/lb of gain; 41 lb of gain)	13.08	0.10
Yardage (hired labor, property, other)	4.91	0.04
Veterinary	0.61	0.00
Trucking (1.172¢/cwt, 250-mile haul)	3.66	0.03
Interest on operating capital (8.5% interest rate)	0.40	0.00
Total costs	**80.62**	**0.64**
Returns	2.51	0.02

Budget 2	Per head	Per pound
Income:		
Slaughter lambs ($63.25/cwt; average weight: 110 lb)	69.58	0.63
Total income	**69.58**	**0.63**
Costs:		
Purchase (65-lb feeder lambs; $68.50/cwt)	44.53	0.40
Feed	12.92	0.12
Hired labor	1.52	0.01
Repairs:		
Machinery and equipment	0.20	0.00
Buildings and fences	0.23	0.00
Fuel, oil, lubricants	0.25	0.00
Storage, warehousing	0.32	0.00
Taxes	0.10	0.00
Insurance	0.10	0.00
Utilities	0.10	0.00
Rents, leases	0.30	0.00
Veterinary medicine	1.75	0.02
Marketing and transportation	3.41	0.03
Total costs	**65.73**	**0.60**
Returns	3.84	0.03

[3] Tables to supplement the figures in this article are available from the author upon request.

Figure 1. Monthly average price indexes for feeder lambs in San Angelo, TX, 1989-93 and 1984-93.

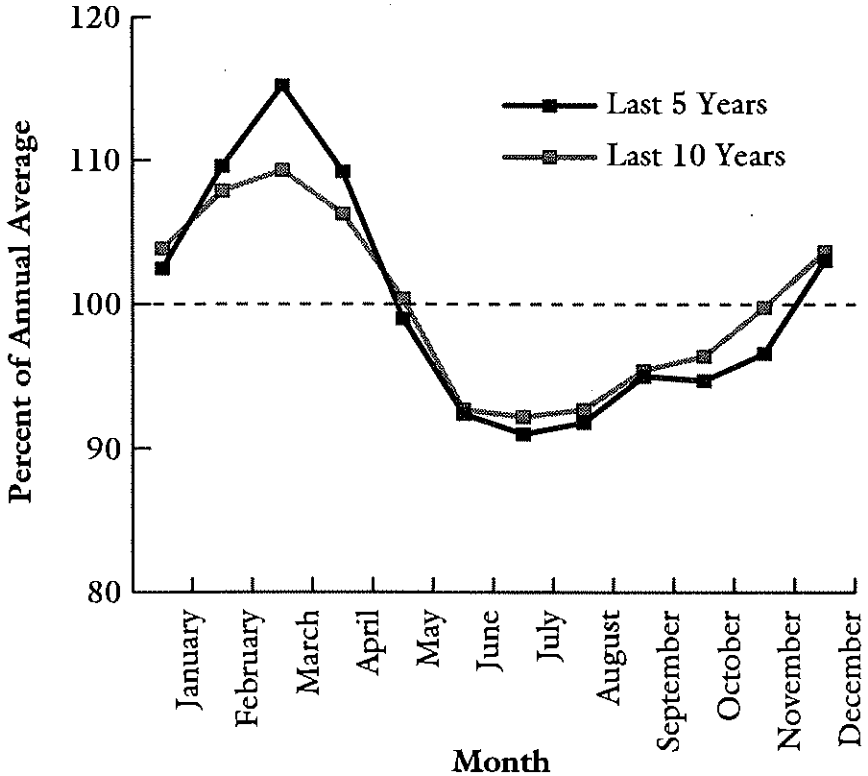
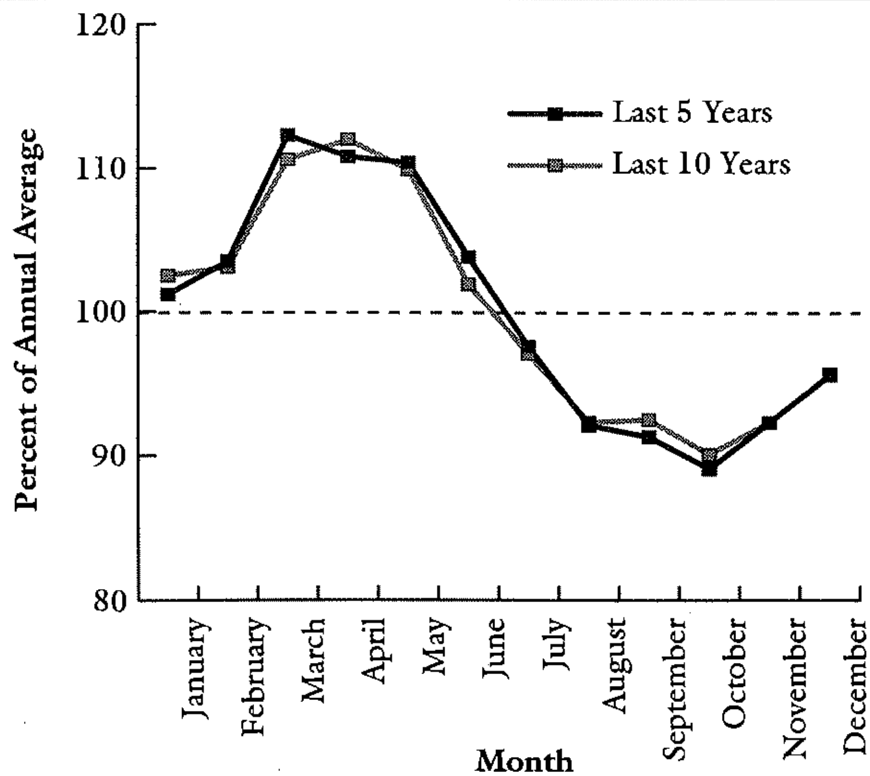


Figure 2. Monthly average price indexes for slaughter lambs in San Angelo, TX, 1989-93 and 1984-93.



the past ten years was 7.8% below the annual average price (100 minus 92.2).

Feeder lamb prices exhibit a seasonal pattern due in part to the seasonal breeding and lambing pattern of sheep. Feeder lamb prices are seasonally highest from December through May and lowest from June through November. Feeder lamb prices on average have reached their annual high point in March and their annual low in July. The five-year seasonal pattern usually is more pronounced than the ten-year pattern and such is the case for feeder lambs. However, both the five-year and ten-year price patterns are similar.

Lamb feeders may use seasonal price indexes to consider when to buy feeder lambs. For example, prices for feeder lambs reached their low in July, with monthly average prices over the past ten years being 92.2% of the annual average price (Figure 1). Assuming an annual average price of $70.00 per hundredweight, then a projected feeder lamb price for July would be $64.54 per hundredweight (0.922 times $70.00).

Seasonal Slaughter Lamb Prices

Figure 2 shows monthly price indexes for slaughter lambs at San Angelo, TX, over the most recent five-year and ten-year periods (1989-93 and 1984-93, respectively). Slaughter lamb prices were seasonally highest from January through June, with the peak in April. Prices were lowest from July to December, reaching their low point in October. Both the five-year and ten-year price patterns are similar.

Seasonal slaughter lamb prices are determined in large part because of consumer eating patterns, especially increased consumption of lamb near Easter. Prices peak just prior to Easter in most years and then decline until reaching the low point in the fall.

Lamb feeders could use seasonal price indexes to find the best time of year to have market-ready slaughter lambs. Referring again to Figure 2, slaughter lamb prices have been seasonally strongest in April. On average, April slaughter lamb prices were 12% above the annual average price over the past ten years. Assume a lamb feeder expects slaughter lamb prices to average $65.00 per hundredweight for a given year, then a projected slaughter lamb price for April would be $72.80 per hundredweight (1.12 times $65.00).

Seasonal Budgeted Lamb Feeding Returns

Budgeted lamb feeding returns also exhibit a seasonal pattern.[4] The seasonal returns pattern results in part from the combined seasonality in feeder lamb and slaughter lamb prices. Thus, budgeted lamb feeding returns do not exactly coincide with either seasonal slaughter lamb or feeder lamb prices but are influenced more by slaughter lamb prices.

Figure 3 shows monthly average lamb feeding returns using both budgets (budget 1 from ASI; budget 2 from OSU) and two periods on feed (60 days, earlier-than-expected marketing; 90 days, later-than-expected marketing). Readers are cautioned that feed costs were not adjusted in this study for feeding period length. Thus, the discussion of feeding period length is limited to an indication of early marketing versus later marketing from the budgeted feeding period.

Figure 3 suggests a difference between lamb feeding returns for budget 1 and budget 2. Similarly, budgeted returns differ for different feeding periods. For the 15-year period, there was a statistically significant difference, at the 0.05 level, in average returns between budget 1 and budget 2 for both feeding period lengths. Budget 1 returns averaged –$1.97 for the 60-day feeding period compared with budget 2 average returns of $3.25 for the same feeding period length. Average returns for the 90-day feeding period were –$1.95 for budget 1 and $3.27 for budget 2. There was no significant difference on average over the entire data period for budgeted 60-day feeding periods versus 90-day feeding periods. Those results might be seen more clearly in Figure 4, which shows the average annual budgeted returns over the

Figure 3. Budgeted monthly average lamb feeding returns, 1979-94.

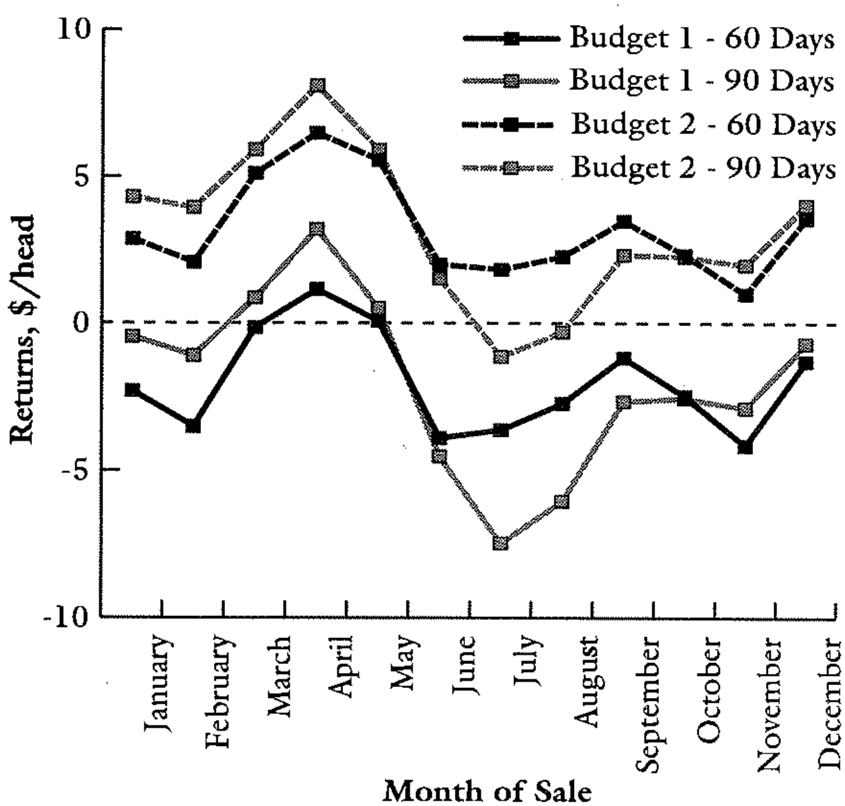
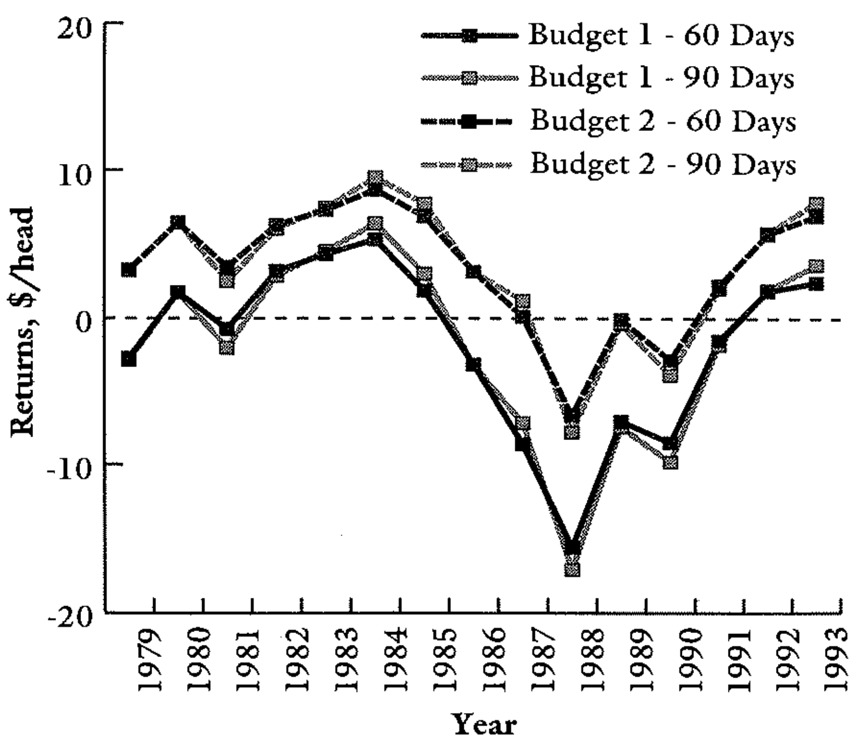


Figure 4. Budgeted annual average lamb feeding returns, 1979-93.



[4] All returns figures are on a per-head basis.

Figure 5. Annual average slaughter lamb prices at San Angelo and annual U.S. commercial lamb and mutton production, 1972-93.

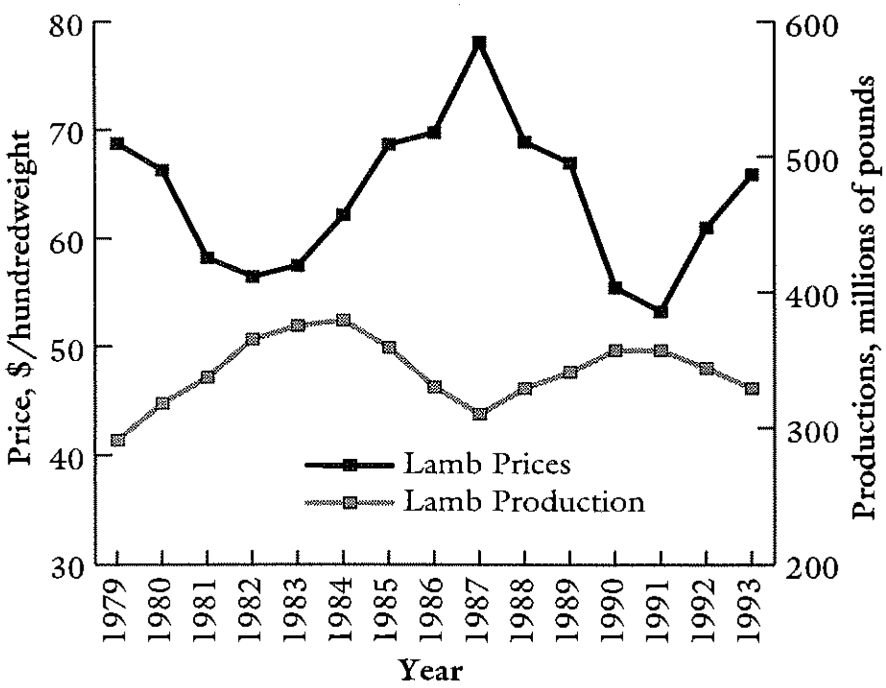
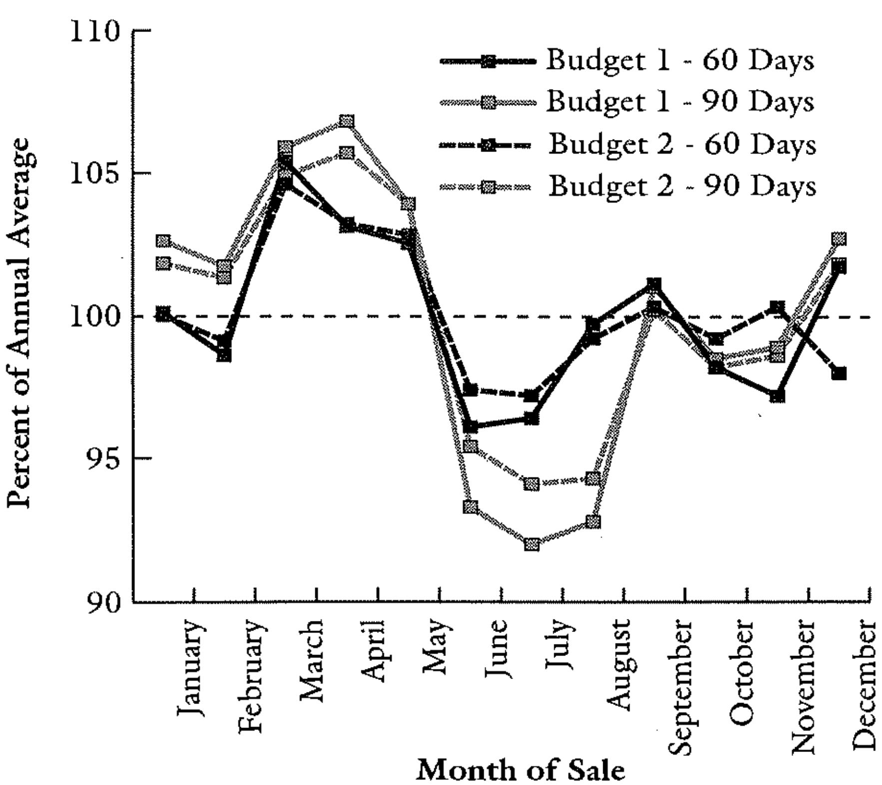


Figure 6. Monthly average indexes for budgeted lamb feeding returns, 1984-93



entire data period. There was a significant difference between the two budgets for some years (e.g., 1979 and 1988-90). However, there was no significant difference between the two feeding period lengths for either budget for any year.

On average (Figure 3), budgeted lamb feeding returns were highest for lambs placed on feed in January and marketed at the end of March or early April and lowest for lambs placed on feed in April and marketed at the end of June or early July. Thus, budgeted profits were above-average for lambs placed on feed and marketed in the following months: January to March/April, February to April/May, March to May/June, October to December/January and December to February/March.

There were no statistically significant month-to-month differences between earlier or later marketing. However, lack of statistical significance was due to the large variability in month-to-month budgeted returns. Figure 3 suggests that economic differences were present and were significant. For example, budgeted returns for early marketing were higher than later marketing from June through September while budgeted returns for later marketing were higher than earlier marketing from November through May. Lamb feeding returns may be higher for lambs marketed from on-feed programs as early as possible during the summer and early fall months. However, lamb feeding returns may be higher for slaughter lambs marketed late in the year and through the peak price period for slaughter lambs if marketed later from the budgeted feeding period rather than earlier.

Returns from earlier or later marketing during the year simply confirm why there are sometimes serious price problems in the spring months. Lamb feeders benefit from the seasonal increase in slaughter lamb prices during the late-winter and early-spring months (Figure 2). Consequently, they hold lambs on feed for longer periods in anticipation of higher prices. What is not accounted for here, however, is the extra weight placed on the market from heavier lambs, which may cause a backlog of lamb in the marketing channel and result in an earlier-than-expected drop in spring wholesale lamb and slaughter lamb prices. Figure 5 shows clearly the inverse relationship using annual data between slaughter lamb prices and domestic lamb production. With few exceptions, production increases lead to price declines and production declines lead to price increases. Month-to-month comparisons of prices versus production do not show this mirror or inverse relationship as well as annual data because of leads and lags in the price and production relationship.

Note also that the direction of market prices, both for feeder lambs and slaughter lambs, affects how above-average or below-average animal performance results in higher or lower profits. For example, consider lambs placed on feed in July and marketed the end of September or first of October. Getting above-average performance in the feedlot and marketing lambs earlier should increase returns ($3.50 per head), compared with getting below-average returns and marketing them one month later ($2.28 per head). However, the reverse is true for lambs placed on feed in September and marketed the end of November or first of December. Getting above-average feedlot performance means marketing lambs earlier (November in this example) when seasonal slaughter lamb prices are lower than in December. Thus, getting below-average animal performance actually increases budgeted returns because of seasonally higher slaughter lamb prices the following month.

Figure 6 shows monthly budgeted return indexes from both lamb feeding budgets and both feeding lengths over the most recent ten-year period (1984-93). Data confirm the seasonal pattern from the four budgeted returns series in Figure 3. The budget used (in this case, whether from ASI or OSU and whether for 60- or 90-day feeding periods) affects the level of returns but not the seasonal pattern of returns.

Little has been said here about risk. Feeder lamb and slaughter lamb prices at times deviate from the normal seasonal pattern. When they do, the estimated seasonal returns pattern in lamb feeding also changes. Market outlook and analysis information is needed to supplement basic lamb feeding budgets. Some lamb feedlot managers have profit projection software which can be used with market information to assess the risk associated with placing lambs on feed at specific times during the year. Lamb feeders need to be aware of how current prices differ from normal seasonal patterns and how the deviation will affect estimated within-year returns.

Conclusions

Calculating profits in lamb feeding is based on the simple economic formula: profit equals total revenue or income minus total costs or expenses. A major component of total revenue is the price of the output (slaughter lambs) and a major component of total costs is the price for the primary input (feeder lambs). Both output and input prices exhibit seasonal patterns. Consequently, lamb feeding returns are also seasonal and may be attributed to the revenue component of the profit equation or the cost component, or a combination of the two.

Lamb feeders need to understand the seasonality of feeder lamb prices, slaughter lamb prices and estimated returns. Such information should be useful in deciding when to place lambs on feed, when to market lambs and whether animals should be pushed or held back during the feeding process. Feeders must recognize, however, that seasonal price indexes or seasonal return indexes do not guarantee within-year patterns will be the same each year. Therefore, seasonal patterns are useful in planning longer-term feeding and marketing strategies, but current and near-term expectations in prices must be considered.

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Efficacy of a Vaccine against *Fusobacterium necrophorum* for Control of Foot Rot in Sheep

J.M. Thompson[1], D.E. Hansen[2] and R.D. McCoy[3]

Summary

A study was conducted to determine the efficacy of a commercial *Fusobacterium necrophorum* vaccine against contagious foot rot in mature sheep. A flock of 700 Dorset and Dorset × Suffolk crossbred ewes was assigned randomly in equal numbers to either a control (C) or treated (V) group. The V group received two subcutaneous 3-ml doses of the *F. necrophorum* bacterin 21 days apart. Ewes in both groups received minimal foot trimming and foot bathing at regular intervals. All ewes were comingled and managed as a single unit during the entire trial. Feet were evaluated at the start of the trial in October, then in April and finally at the end of the trial in August, using a scoring system from 0 to 3 (0 = No Foot Rot; 3 = Severe Undermining of Sole). Foot scores were lower ($P < 0.05$) for the V group than for the C group at the April and August scoring periods. At the end of the trial, vaccination reduced ($P < 0.01$) the incidence of foot rot by 36%. Vaccination of previously uninfected ewes reduced ($P < 0.01$) the rate of new infection. Vaccination of infected ewes resulted in a significant ($P < 0.01$) cure rate of 34%. There were no differences in the incidence of foot rot due to age of ewe or breed. Vaccination can be used to reduce the incidence of contagious foot rot in sheep, especially if used in conjunction with other management practices to control foot rot.

Key words: sheep, vaccines, foot rot, immunization, *Fusobacterium necrophorum*.

Introduction

Ovine foot rot is a synergistic infection of two gram-negative anaerobic bacteria, *Bacteriodes nodosus* and *Fusobacterium necrophorum*. Since 1984, a commercial foot rot vaccine for *B. nodosus* has been available in the U.S. The vaccine contains eight British serotypes that have been shown to cross-react with at least 14 of the 20 identified serotypes of *B. nodosus* in the U.S. (Smith et al., 1990). Research with this vaccine has produced varied results. Studies that included no routine foot care reported therapeutic reductions in foot rot incidence of 27% to 54% (Mulvaney et al., 1984; Glenn et al., 1985; Kennedy et al., 1985; Bulgin et al., 1986), while the therapeutic reduction of foot rot has been greater (up to 83%) when trimming and foot bathing have been included with the use of the *B. nodosus* vaccine (Glenn et al., 1985; Bulgin et al., 1986; Lewis et al., 1989).

In 1992, a vaccine containing the *F. necrophorum* bacterium was made available in the U.S. Berg (1990) reported 61% to 88% reductions in foot rot in field trials using this vaccine. Given the limited data collected under various levels of management, a study was conducted to determine the efficacy of a *F. necrophorum* vaccine in a commercial ewe flock with a history of contagious foot rot problems.

Materials and Methods

A commercial flock of 700 Dorset and Dorset × Suffolk ewes was used to evaluate the ability of a vaccine (Volar, Miles Inc. Animal Health Products, Shawnee Mission, KS) to prevent or cure foot rot. The ewes were assigned randomly in equal numbers to either a control (C) or treated (V) group.

Vaccination and Treatment

Ewes in both groups received minimal foot trimming and foot bathing using a 10% formaldehyde or 10% zinc sulfate solution at intervals of 10 or more days depending upon the conditions. Ewes in V group received two subcutaneous 3-ml doses of the *F. necrophorum* bacterin 21 days apart. Minimal foot trimming in this trial

[1] Department of Animal Sciences, Oregon State University, Corvallis, OR 97331.

[2] College of Veterinary Medicine, Oregon State University, Corvallis, OR 97331.

[3] Douglas County Extension Livestock Agent, Roseburg, OR 97470.

meant that only feet with excessive horn growth were trimmed. All ewes were co-mingled and managed as a single unit during the entire trial.

Foot Scoring Method

At the start of the study the feet of each ewe in the trial were subjectively scored for foot health. Evaluators adhered to the following criteria for scoring: 0 = No Foot Rot; 1 = Initial Lesion of the Interdigital Skin Between the Toes or at the Heel; 2 = Advanced Lesion with Some Undermining of the Sole of one or both Toes; and 3 = Undermining of the Sole and Abaxial Wall with a Foul-Smelling Exudate of one or both Toes.

Score values for all four feet of each ewe were combined resulting in a single score for that ewe. The individual foot scores were used throughout the trial to assess cure rate and infection rates. The average scores were used to compare groups at the end of the trial.

All ewes were scored in October at the start of the trial (initial), in April (intermediate) and in August at the end of the trial (final). The cooperator noted any ewes that were limping or showing any other obvious signs of foot problems throughout the trial period.

Statistical Analysis

Analysis of the data was performed as a completely random experimental design. Comparisons between incidence rates, protective and cure rates of the treatment groups were made using the methods described by Fienberg (1983) for the analysis of cross-classified categorical data. Analysis of Variation (ANOVA) and appropriate Mantel-Haenzel techniques were used to analyze the contribution that the variables "ewe-age" and "ewe-breed" made to the variation between the incidence rates of the treatment groups. Relative risk and vaccine efficacy values were calculated using methods described by Martin et al. (1987) and Kleinbaum and Kupper (1982).

Results and Discussion

Although 700 ewes started the study, complete data were collected on 689 ewes. The difference represents ewes that died or were culled from the flock for various reasons unrelated to foot rot. There were 347 non-vaccinated ewes in the C group and 342 ewes in the V group.

Mean foot scores for the three scoring periods are presented in Table 1. No difference was observed in the mean foot score for the C and V groups at the start of the trial. However by the intermediate scoring period there was a difference ($P < 0.05$) with the V group having a lower score than the C ewes (1.50 versus 1.77), indicating a response to the vaccine. At the final scoring period, the V group continued to have a lower ($P < 0.05$) overall mean foot score. The trends noted in this study for mean foot scores, being higher in the late autumn and spring (when average precipitation is higher) and lower in the drier summer, follow those reported by Lewis et al. (1989) for ewes in western Oregon.

The variations in foot rot incidence (percent ewes in the flock with a mean foot score greater than 0 [zero]) for both groups was calculated (Table 2). At the beginning of the trial no differences were noted in the incidence of foot rot: 57% (198/347) of C ewes versus 55% (188/342) of V ewes. At the intermediate period the infection rates differed ($P < 0.01$) with a reduction in incidence in the V group and no change in C ewes. At the final evaluation the infection rates continued to differ ($P < 0.01$) between the C and V at 55% (191/347) and 35% (120/342), respectively. This represents a 36% reduction in the overall incidence of foot rot in the vaccinated group. Previous studies that have included no routine foot care practices, as followed in this trial, report reductions in foot rot incidence from 27% to 54% with vaccinations using the *B. nodosus* bacterin (Mulvaney et al., 1984; Glenn et al., 1985; Kennedy et al., 1985; Bulgin et al., 1986).

Table 1. Mean foot score for the control (C) and treated (V) groups at the three scoring periods.

Group	Number of ewes	Initial ± SEM (October)	Intermediate ± SEM (April)	Final ± SEM (August)
		Foot scoring period		
C	347	$2.01^{a} \pm 0.13$	$1.77^{a} \pm 0.10$	$1.22^{a} \pm 0.09$
V	342	$1.99^{a} \pm 0.13$	$1.50^{b} \pm 0.09$	$0.92^{b} \pm 0.08$

[a,b] Means in the same column without a common superscript differ ($P < 0.05$)

Table 2. Foot rot incidence and vaccine efficacy for control (C) and treated (V) at the three evaluation periods.

	Evaluation period					
	Initial (October)		Intermediate (April)		Final (August)	
Group	Incidence, %	Efficacy, %	Incidence, %	Efficacy, %	Incidence, %	Efficacy, %
C	57^{a}	–	56^{a}	–	55^{a}	–
V	55^{a}	na	39^{b}	52	35^{b}	57

[a,b] Values in same column without a common superscript differ ($P < 0.01$)

Besides the reduction in the incidence of foot rot in the V group, the protective value of the vaccine was measured in another way (Table 3). The number of ewes that were initially free of foot rot and the impact of vaccination on their foot health was recorded. The percent of non-vaccinated ewes that became infected was 50% (74/149) versus 24% (37/154) ($P < 0.01$) of the vaccinated ewes. The calculated vaccine effectiveness to prevent disease was 69%, which is in agreement with results reported by Berg (1990) who found an efficacy of 61% to 82% for the *F. necrophorum* vaccine in field trials.

The ability of the vaccine to cure foot rot was evaluated. The cure rate was the proportion of ewes that were infected at the start of the trial and had a score of 0 (zero) at the end of the trial (Table 4). The cure rate was less ($P < 0.01$) for the C ewes (6%) when compared to the V group (34%). The effectiveness of the vaccine to cure infected feet was 87%.

Age of the ewe was analyzed as a risk factor for foot rot and for its impact on disease incidence. Analysis for the differences in infection rate among age groups of vaccinated and non-vaccinated ewes failed to detect any statistically significant association between age and foot rot incidence. Breed of ewe also was analyzed as a potential risk factor. No significant differences could be detected between the breeds in response to the vaccine or incidence of foot rot.

Conclusions

Results of this study indicate that for the particular *F. necrophorum* type in the flock, the vaccine had a measurable impact. In this case of minimal foot care, foot rot incidence was reduced with the vaccine. The reduction observed in this flock would probably not be sufficient to get rid of the disease. Maximum benefits from the vaccine may be attained when it is used against susceptible agents and in conjunction with routine foot trimming and the use of foot baths.

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Table 3. Rate (percent) of non-infected ewes that became infected during the trial for the control (C) and treated (V) groups.

Group	Percentage non-infected to infected	Vaccine efficacy, %
C	50	–
V	24[a]	69

[a] $P < 0.01$

Table 4. Cure rate (percent of infected ewes that became non-infected) during the trial for the control (C) and treated (V) groups.

Group	Cure rate, %	Vaccine efficacy, %
C	6	–
V	34[a]	87

[a] $P < 0.01$

Effects of Style and Character of U.S. Mohair on Top Properties[1,2,3]

D.L. Minikhiem[4], C.J. Lupton[4,5], F.A. Pfeiffer[4], K. Qi[4] and J.R. Marschall[4]

Summary

Twenty-nine commercial lots of mohair were sampled and tested in the grease state and again after top manufacturing to: 1) establish the impact of objectively measured style and character in greasy mohair staples on fiber characteristics of top produced on the worsted system; and 2) determine correlations among staple and top fiber characteristics. Greasy mohair staples were measured for style, character, yield, average fiber diameter (AFD) and standard deviation (SD) of AFD, average staple length (ASL) and SD of ASL, med and kemp. The resulting top was evaluated for AFD and SD of AFD, average fiber length (AFL) and SD of AFL, med and kemp. Style of greasy mohair was not correlated with top AFL ($P > 0.55$) or SD of AFL ($P > 0.99$). Similarly, character of greasy mohair and top AFL ($P > 0.28$) and SD of AFL ($P > 0.43$) were not correlated. In contrast, style was negatively correlated with kemp in top ($r = -0.63$, $P < 0.0003$) and character was negatively correlated with top AFD ($r = -0.50$, $P < 0.006$), SD of top AFD ($r = -0.47$, $P < 0.01$), staple AFD ($r = -0.61$, $P < 0.0004$) and SD of staple AFD ($r = -0.57$, $P < 0.002$).

Objectively determined style and character have little impact on fiber length characteristics of mohair top. However, style does provide an indication of kemp in top and character is related to average fiber diameter, diameter variability and med content of top somewhat justifying continued interest in subjectively assessed style and character of raw mohair.

Key words: mohair, style, character.

Introduction

Although few studies exist on the effects of mohair style and character on topmaking and spinning performance, most registered breeders and some manufacturers strongly contend that these characteristics should be considered when selecting Angora goats for mohair production. In this study, style is defined as the number of twists or curls per centimeter of relaxed staple, whereas character is the number of crimps or waves per centimeter of relaxed staple (Hunter, 1993). Topmakers claim that mohair having good style produces top with "better" fiber length characteristics (longer mean fiber length, more uniform distribution of fiber length) than mohair with poor style but reasonable character. Strydom and Gee (1985) found that wave frequency affects different measures of fiber length and contributes to variation in top and noil yields. However, this study involved a relatively narrow range of style and character, namely, good to super style (South African terminology) kid, young goat and adult mohair. In a similar study, Turpie (1985) concluded that mohair with good style and character showed more uniformity in the staple cross section. Compared to U.S. goats, many South African Angora goats exhibit a higher degree of style because South African breeders have selected based on this trait for a long time. Because it has never been proven that style is truly advantageous in any aspect of processing or in the final product, this trait has not been a primary selection criterion in many U.S. Angora goat flocks. As a result, true ringlet types do not comprise a significant proportion of the U.S. mohair clip (Lupton, 1992). Because of the uncertainty surrounding this issue and the lack of research results, this study was conducted to establish the importance of style and character in determining top properties.

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4 Texas Agricultural Experiment Station, Texas A&M University System, San Angelo, TX 76901.

5 To whom correspondence should be addressed.

Materials and Methods

Twenty-nine lots of mohair (24 commercial lots from Texas International Mohair, Inc., Brady, TX; and five lots of about 200 pounds each that were processed at the International Textile Center, Lubbock, TX) were grab-sampled and then evaluated at the Texas Agricultural Experiment Station's Wool and Mohair Research Lab, San Angelo, TX, in the grease state and again after top manufacturing. The five small lots were obtained from warehouses in Texas and were representative of fine kid, average kid, yearling goat, fine adult and average adult mohair. The 24 commercial lots were representative of a broad range of U.S. mohair in terms of style, character and fiber diameter. Fifty staples were removed at random from each lot and later placed onto a black velvet board where their relaxed and straightened lengths were measured. The total number of ringlets were counted, and the number of ringlets per centimeter was calculated. Likewise, the staples were examined for total number of waves, and the number of waves per centimeter was calculated. A photographic record was made of the 50 staples from each lot so that objectively measured style and character values could be associated with commonly used trade descriptions. Greasy mohair was evaluated in terms of mean staple length (relaxed and straightened) and SD, style and character. In addition, clean mohair fiber present (CMFP) of the greasy mohair was determined following the American Society for Testing and Materials (ASTM) D584 procedure (ASTM, 1993b). The AFD and SD were measured using the Optical Fibre Diameter Analyser (OFDA) according to the procedures outlined in a draft method (International Wool Textile Organization [IWTO], 1993). The ASTM standard microprojection method D2968 (ASTM, 1993d) was followed to determine med and kemp content of staples and tops. Average fiber length and standard deviation (AFL and SD) in top as well as AFD and SD of AFD were measured at Yocom-McColl Testing Laboratories, Inc., Denver, CO, using ASTM Standard Test Methods D519 (ASTM, 1993a) and D2130 (ASTM, 1993c), respectively.

Statistical Analysis

Simple statistics (means and standard deviations) for raw staple and top characteristics were calculated using the MEANS procedure of SAS (1988). Pearson correlation coefficients between top and greasy staple properties were calculated using the CORR procedure (SAS, 1988).

Results and Discussion

The mean, minimum, maximum and standard deviation values of most of the fiber properties measured on greasy staples and mohair top are presented in Table 1, which illustrates the broad range of U.S. mohair types used in this study. It is noted that while mean percentages of med content were 0.75 and 0.76 for greasy and top mohair, respectively, the maximum med content was appreciably higher for greasy mohair compared to top. This discrepancy is probably due to sampling technique. Whereas top fibers are well blended and truly representative, grease samples are grab samples and are therefore less representative. Lack of uniformity in grease samples could be responsible for this incongruity in results. Table 2 summarizes correlation coefficients between characteristics measured on greasy staples versus mohair top, and Table 3 contains similar information for style and character versus greasy staple properties.

Table 1. Mean, minimum, maximum and standard deviation (SD) values of fiber characteristics for 29 lots of mohair.

Greasy characteristics	Mean	Minimum	Maximum	Mean SD (within sample)
Relaxed staple length, cm	9.93	7.50	12.70	1.93
Straightened staple length, cm	12.85	10.70	15.60	1.92
Ringlets/cm (style)	0.086	0	0.150	0.091
Waves/cm (character)	0.452	0.300	0.600	0.141
Clean mohair fiber present, %	79.91	68.34	86.74	—
Fiber diameter, µm	31.98	23.20	39.20	9.63
Med content, %	0.75	0.15	7.50	—
Kemp content, %	0.38	0.05	1.25	—
Top characteristics:				
Fiber length, cm	4.25	3.52	4.89	1.31
Fiber diameter, µm	32.42	23.80	38.00	9.72
Med content, %	0.76	0.10	1.60	—
Kemp content, %	0.47	0.10	1.20	—

Style of greasy mohair staples was not correlated ($P > 0.1$) with any of the characteristics measured on top except kemp. In this latter case, a significant negative correlation ($r = -0.63$, $P < 0.0003$) was observed (Table 2). Style was also correlated with med and kemp content in greasy staples ($r = 0.35$ and 0.33, respectively, $P < 0.1$; Table 3). This positive relationship between style and kemp in greasy mohair was contrary to the negative correlation of style and kemp in top. As stated previously, sampling technique involving grab samples of greasy mohair probably contributed to this disparity in results. Character of mohair staples was not correlated ($P > 0.1$) with either AFL or SD of AFL of top. In contrast, character of greasy mohair staples was correlated with AFD and SD of AFD of the raw material ($r = -0.61$ and -0.57, respectively, $P < 0.01$). The values of the correlation coefficients were somewhat reduced but still highly significant for the character versus AFD and SD of AFD of tops ($r = -0.50$ and -0.47, respectively, $P < 0.01$; Table 2). Character was not significantly correlated ($P > 0.1$) with any other property measured in the raw material (Table 3). However, a correlation between character and med content of top was observed ($r = -0.36$, $P < 0.1$; Table 2).

Conclusions

It is apparent from this study that objectively determined style and character have little impact on fiber length characteristics of mohair top. However, style does provide an indication of kemp in top and character is related to average fiber diameter, diameter variability and med content of top. These latter relationships somewhat justify producers' and processors' continued interest in subjectively assessed style and character of raw mohair. Further, it is recognized that adequate style and character provide the desired esthetics necessary for successful Angora goat showing. However, for production-oriented selection purposes, breeders are strongly advised not to rely solely on style and character of fleeces but to use objectively measured values for specific, economically important traits.

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Table 2. Correlation coefficients between characteristics measured on greasy staple and mohair top for 29 lots of mohair.

	Greasy staple characteristics												
Top characteristics	S[a]	SD of S[b]	C[c]	SD of C[d]	RSL[e]	SD of RSL[f]	SSL[g]	SD of SSL[h]	CMFP[i]	AFD[j]	SD of FD[k]	Med[l]	Kemp[m]
AFL[l]	-0.11	-0.07	0.20	0.26	0.35[n]	0.39[o]	0.60[q]	0.41[o]	-0.12	0.15	0.07	0.20	-0.10
SD of AFL[m]	-0.00	0.01	0.15	0.04	0.42[o]	0.35[n]	0.65[q]	0.47[o]	-0.02	-0.02	-0.12	0.04	-0.21
AFD	-0.10	-27	-0.50[p]	-0.02	-0.27	0.13	-0.21	0.03	0.31	0.87[q]	0.72[q]	-0.13	-0.05
SD of AFD	-0.19	-0.27	-0.47[p]	-0.03	-0.22	0.06	-0.19	-0.00	0.30	0.82[q]	0.76[q]	-0.15	-0.02
Med	-0.18	-0.33[n]	-0.36[n]	-0.09	0.13	0.18	0.06	0.20	0.25	0.43[o]	0.43[o]	-0.04	0.10
Kemp	-0.63[q]	-0.25	0.07	0.08	-0.13	-0.09	-0.25	-0.06	-0.23	-0.06	0.01	-0.32[n]	-0.18

[a] S = style.
[b] SD of S = standard deviation of style.
[c] C = character.
[d] SD of C = standard deviation of character.
[e] RSL = relaxed staple length.
[f] SD of RSL = standard deviation of relaxed staple length.
[g] SSL = straightened staple length.
[h] SD of SSL = standard deviation of straightened staple length.
[i] CMFP = clean mohair fiber present.
[j] AFD = average fiber diameter.
[k] SD of FD = standard deviation of fiber diameter.
[l] AFL = average fiber length.
[m] SD of AFL = standard deviation of average fiber length.
[n] $P < 0.1$.
[o] $P < 0.05$.
[p] $P < 0.01$.
[q] $P < 0.001$.

Table 3. Correlation coefficients for style and character versus other greasy staple characteristics.

	Greasy staple characteristics								
Criteria	RSL[a]	SD of RSL[b]	SSL[c]	SD of SSL[d]	CMFP[e]	AFD[f]	SD of FD[g]	Med	Kemp
Style	-0.18	-0.25	-0.10	-0.32[h]	0.25	-0.25	-0.24	0.35[h]	0.33[h]
Character	-0.14	-0.19	0.09	-0.10	-0.22	-0.61[j]	-0.57[i]	0.27	0.25

[a] RSL = relaxed staple length
[b] SD of RSL = standard deviation of relaxed staple length
[c] SSL = straightened staple length
[d] SD of SSL = standard deviation of straightened staple length
[e] CMFP = clean mohair fiber present
[f] AFD = average fiber diameter
[g] SD of AFD = standard deviation of average fiber diameter.
[h] $P < 0.1$.
[i] $P < 0.01$.
[j] $P < 0.001$.

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Impact of the Elimination of Incentive Payments and Increases in Grazing Costs on Colorado Sheep Ranches

V.G. Carande[1], P.H. Gutierrez[2], S.B. LeValley[3] and R.L. Sharp[4]

Summary

This study analyzed the impact of the elimination of the wool incentive payment and increases in fee and non-fee grazing costs on the financial performance of Colorado extensive/rangeland sheep operations. Six cases were studied. Case 1 was the baseline. It defined a representative sheep ranch in western Colorado with no policy changes. Case 2 incorporated the phase-out of the incentive payment from full payment in 1994 to no payment in 1997. Case 3 incorporated an increase in the grazing fee from $1.98 per animal unit month (AUM) in 1994 to $3.96 per AUM in 1997. Case 4 incorporated an increase of 10% in non-fee grazing costs over the 1995-1999 period. Case 5 combined the phase-out of the incentive payment with the increase in grazing fee. Case 6 combined the phase-out of the incentive payment with the increase in grazing fee and non-fee grazing costs. All cases were simulated for 0, 20, 30 and 40% debt levels. The incentive payment showed the most marked effect on net cash income, followed by the grazing fee and by the non-fee grazing costs. The phase-out of the incentive payment decreased net cash income by 101% at 0% debt and by 136% at 40% debt. The combined effect of the phase-out of the incentive payment and grazing fee decreased net cash income by 116% at 0% debt and by 158% at 40% debt. The combined effect of the three policies decreased net cash income by 131% at 0% debt and by 177% at 40% debt.

Key words: risk analysis, sheep industry, agricultural policy, grazing fees.

Introduction

Colorado ranked eighth in sheep production and first in sheep feeding among sheep-producing states in 1992. The 1,800 Colorado producers maintained the fourth largest inventory of sheep and lambs in the nation. Colorado 1992 wool production totaled $4.4 million and cash receipts from sheep and lamb production totaled $43.9 million. Sheep operations play an important role in the stability of Colorado rural communities. Colorado sheep producers are facing new policies with both short- and long-term consequences affecting their operations. The elimination of the National Wool Act incentive payment will reduce cash receipts from wool production. The proposed Rangeland Reform '94 (Federal Register, 1994) calls for higher grazing fees and more regulatory provisions regarding the grazing of public lands. The combined impact of these policies on the survival of Colorado sheep operations is uncertain. This report presents an analysis of the impact of the phase-out of the wool incentive payment, increases in grazing fees and increases in non-fee grazing costs on the financial performance and survival of a representative Colorado sheep ranch.

The Baseline and Policy Cases: Assumptions and Procedure

The assumptions used in this analysis were designed to be consistent with a typical western Colorado sheep operation. Western Colorado sheep producers rely on access to federal grazing lands for forage. Wool sales and the wool incentive payment constitute a significant portion of the annual cash receipts for many of these producers. A representative extensive/rangeland Colorado sheep ranch was developed from information obtained through an informal survey

[1] Postdoctoral Fellow, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO 80523.

[2] Associate Professor, Department of Agricultural and Resource Economics, Colorado State University, Fort Collins, CO 80523.

[3] Extension Sheep Specialist, Department of Animal Science, Colorado State University, Fort Collins, CO 80523.

[4] Extension Farm/Ranch Management Economist, Colorado State University, Fort Collins, CO 80523.

of producers and Cooperative Extension agents.

The representative Colorado sheep ranch had 2,000 acres of deeded land and 500 acres of private leased land. It maintained 1,500 mature ewes, 300 raised replacement ewes and 40 rams. Total grazing requirements were 4,416 AUMs. Deeded land provided 442 AUMs and federal sources provided the remaining 3,974 AUMs at $1.98 per AUM (Table 1). Lamb crop weaned was 116% and lamb sale weights were 95 pounds for ewe lambs and 105 pounds for wether lambs. Total wool production was 14,200 pounds. The ranch had one paid employee and received no income from outside sources.

The analysis was performed using the Farm Level Income and Policy Simulator (FLIPSIM) model. For further references on the model see Richardson et al. (1993). The model required approximately 270 input variables specifying production, operating costs and financial characteristics of the ranch. Lamb prices (Table 2) were forecasted with a harmonic regression model developed by Carande (1994). Wool prices were set at $0.60 per pound for the entire seven-year simulation period. Annual interest and inflation rates applied to input prices were taken from the Food and Agricultural Policy Research Institute (FAPRI) January 1994 Baseline (Richardson et al. 1994). FLIPSIM estimated approximately 80 output variables including present value of annual cash receipts, annual cash expenses, annual net worth and annual net cash income for each year of the time horizon. It also calculated the seven-year average net cash income, change in real net worth and average return to assets. Using production and price probabilities through 100 iterations, the model also calculated the ranch's probability of success, survival and lower real equity.

The six policy cases analyzed are listed in Table 3. They included the baseline and five policy cases. Case 1, the baseline, assumed full incentive payment at a constant rate of 270% throughout the entire simulation. Federal grazing fees were kept constant at $1.98 per

Table 1. Characteristics of the representative Colorado sheep ranch.

Grazing Requirements:	
Total AUMs	4,416
Federal leases, AUMs	3,974
Federal grazing fee, $/AUM	1.98
Private leases, AUMs	442
Private lease cost, $/AUM	9.00
Flock Characteristics:	
Ewes, no.	1,500
Replacements, no.	300
Rams, no.	40
Efficiency and Production Measures:	
Lamb crop weaned, %	116
Lamb sale weight, lb:	
Ewe lambs	95
Wethers	105
Wool production	14,200

Table 2. Projected prices, interest rates and inflation rates used in the baseline.

	Year						
	1994	1995	1996	1997	1998	1999	2000
Nominal Prices:							
Feeder lamb price, $/cwt	67.50	72.90	76.04	75.80	72.60	67.75	63.35
Wool price, $/lb	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Wool support fraction, %	270	270	270	270	270	270	270
Annual Rate of Inflation for:							
Used machinery	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Fuel and lube	0.055	0.063	0.021	0.009	0.018	0.014	0.036
Hired labor	0.02	0.021	0.021	0.022	0.022	0.023	0.025
Misc. costs and insurance	0.032	0.033	0.029	0.028	0.028	0.033	0.033
Inputs for livestock	0.032	0.033	0.029	0.028	0.028	0.033	0.033
Other production costs	0.032	0.033	0.029	0.028	0.028	0.033	0.033
Land values	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Building values	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Consumer Price Index	150.2	156.2	162.5	168.7	175.2	182	189.1
Interest Rates, %:							
Long-term loans	0.069	0.073	0.077	0.081	0.085	0.086	0.085
Intermediate loans	0.08	0.086	0.09	0.096	0.1	0.102	0.104
Operating loans	0.075	0.808	0.086	0.091	0.095	0.097	0.099

AUM and no additional non-fee grazing expenses were added to the operating costs. Case 2 evaluated the phase-out of the incentive payment. Historically, the incentive payment has represented 15% to 30% of the total receipts of western sheep operations. For purpose of this analysis, the wool incentive payment was received in full in 1994 for the 1993 clip. It was then reduced to 75% in 1995 for the 1994 clip, 50% in 1996 for the 1995 clip, and phased-out completely thereafter. Income from wool after 1996 was based solely on receipts from grease wool sales. Case 3 evaluated a gradual increase in the federal grazing fee from $1.98 per AUM in 1994 to $2.77 per AUM in 1995, $3.50 per AUM in 1996 and $3.96 per AUM in 1997 through the year 2000. Case 4 evaluated an increase in non-fee grazing costs due to increased public land grazing regulations because of Rangeland Reform '94. An arbitrary 2% of $19.87 per AUM was added each year for five years, beginning in 1995. The $19.87-per-AUM non-fee grazing cost was based on estimates by Redmond et al. (1993). The year 2000 non-fee grazing cost was held constant at the 1999 non-fee grazing cost level. Case 5 combined the phase-out of the incentive payment (case 2), with the increase in grazing fee (case 3). Case 6 combined the incentive payment phase-out (case 2), the grazing fee increase (case 3) and the non-fee grazing cost increase (case 4). The analysis was performed at 0, 20, 30 and 40% intermediate- and long-term debt levels to provide a range inclusive of the majority of Colorado sheep operations. It is estimated that the average debt level of Colorado sheep ranches is approximately 20%.

Impact of Policies on Financial Performance and Survival

The listing for the main financial parameters obtained from the 20% debt analysis is presented in Table 4. The results for the 0, 30 and 40% debt cases can be found in Carande (1994). Not unexpectedly, net cash income was heavily influenced by the cyclical trend of lamb prices. It peaked in 1996, the same year the projected peak in Colorado lamb prices was observed. Net cash income declined beyond 1996. The degree of the decline depended on the type of policy and the level of debt imposed on the operation. Of the three single-policy cases, the phase-out of the wool incentive payment (case 2) showed the largest decline in net cash income. At 0% debt, the net cash income in the year 2000 was 101% lower than in 1994. At 20% debt, it was 117% lower than in 1994 (Figure 1). At 30% debt, it was 129% lower than in 1994. At 40% debt, it was 136% lower than in 1994. The largest decline of net cash income for all debt levels was observed when all policies were combined (Case 6). At 0% debt, the net cash income in the year 2000 was 131% lower than in 1994. At 20% debt, it was 152% lower than in 1994. At 30% debt, it was 162% lower than in 1994. At 40% debt, it was 177% lower than in 1994.

All cases showed a decline in net worth, even the baseline (Table 4). Of the single-policy cases, the phase-out of the wool incentive payment showed the largest decline in net worth at all debt levels. The average decline in real net worth over the seven-year time horizon was 0.6% at 0% debt, 2.9 at 20% debt, 5.5% at 30% debt and 9.8 at 40% debt. Of the combined-policy cases, case 6 showed the largest decline in net worth. This decline was 33.2% at 0% debt, 48.5% at 20% debt, 60.4% at 30% debt and 79.4% at 40% debt.

The probability of success is the chance that the farm will earn a return on initial equity greater than 5.76%. At 0% debt, the baseline showed a probability of success of 88%. At the same level of debt, the phase-out of the wool incentive payment decreased the probability of success to 53%, the increase in grazing fee to 82%, the increase in non-fee grazing costs to 83%, the combined payment and grazing fee to 40% and the combined payment, grazing fee and non-fee grazing costs to 32%. Further reduc-

Table 3. Assumptions for the six cases analyzed.

Case	Policy variable	Year 1994	1995	1996	1997	1998	1999	2000
Baseline:								
Case 1	Percent of wool payment	100	100	100	100	100	100	100
	Grazing fee, $/AUM	1.98	1.98	1.98	1.98	1.98	1.98	1.98
Single-Policy Cases:								
Case 2	Percent of wool payment	100	75	50	0	0	0	0
Case 3	Grazing fee, $/AUM	1.98	2.77	3.50	3.96	3.96	3.96	3.96
Case 4	Increase in non-fee grazing cost, $	0.00	1579.30	3158.50	4737.80	6317.10	7896.30	7896.30
Combined-Policy Cases:								
Case 5	Percent of wool payment	100	75	50	0	0	0	0
	Grazing fee, $/AUM	1.98	2.77	3.5	3.96	3.96	3.96	3.96
Case 6	Percent of wool payment	100	75	50	0	0	0	0
	Grazing fee, $/AUM	1.98	2.77	3.50	3.96	3.96	3.96	3.96
	Non-fee grazing cost, $	0.00	1579.30	3158.50	4737.80	6317.10	7896.30	7896.30

tions in the probability of success were observed at higher debt levels. At 20% debt (Figure 2), the combined payment and grazing fee affected significantly the chances of financial success. This impact was even greater at 30% and 40% debt. Probability of success for the payment and grazing fee combined declined to 18% at 30% debt, and to 12% at 40% debt. When all three policies were combined, probability of survival declined to 12% at 30% debt and to 7% at 40% debt.

The probability of survival is the chance that the ranch will remain solvent through the seven-year time horizon. Solvency is defined as an equity-to-asset ratio greater than 15%. At 0% debt, probability of survival was 100% for all cases studied. At 20% debt (Figure 3), probability of survival decreased for the case of the phase-out of the wool incentive payment (case 2), for the case of the phase-out of the incentive payment and the increase in grazing fee (case 5) and for the case where all three policies were combined (case 6). At 30% debt, probability of survival was 100% only for the baseline. At this level of debt, probability of survival decreased to 91% for the phase-out of the wool incentive payment, 99% for the increase in grazing fee, 99% for the increase in non-fee grazing costs, 86% for the payment and grazing fee combined and 81% for the payment, grazing fee and non-fee grazing cost combined. At 40% debt, probability of survival decreased to 97% for the baseline case, 81% for the phase-out of the wool incentive payment, 93% for the increase of the grazing fee, 93% for the increase in non-fee grazing costs, 74% for the payment and grazing fee combined and 63% for the payment, grazing fee and non-fee grazing cost combined.

Conclusions

Based on the assumptions made in this analysis, the phase-out of the National Wool Act incentive payment and policy changes regarding grazing in federal lands were detrimental to the financial performance and chances of survival of extensive sheep ranches in Colorado. When each policy was analyzed separately, the phase-out of the wool incentive payment had the greatest negative effect on the financial performance of the representative Colorado sheep ranch. An objective comparison between the elimination of the incentive payment and the increase in grazing fees indicated a greater economic impact from the loss of the wool incentive payment.

The impact of policies on the financial performance of the representative Colorado sheep ranch was aggravated by higher levels of debt. Given the low annual net cash income and low probability of success shown by the combination of the phase-out of the incentive payment, the increase in the grazing fee increase and the increase in non-fee grazing cost, debt levels

Table 4. Financial performance of the simulated representative Colorado sheep ranch at 20% debt for the baseline (case 1), wool payment phase-out (case 2), grazing fee increase (case 3), non-fee grazing cost (case 4), wool payment and grazing fee combined (case 5) and wool payment, grazing fee and non-fee grazing fee combined (case 6).

	Case					
	1	2	3	4	5	6
Average change in real net worth, %[a]	-2.86	-31.59	-9.81	-8.07	-41.39	-48.45
Present value net worth, $1,000[b]	362.98	255.63	337.01	343.54	219.01	192.64
Average return to assets, %[c]	5.04	1.07	4.07	4.27	-0.12	-1.09
Average annual cash receipts, $1,000[d]	146.10	123.75	146.10	146.10	123.64	123.49
Average annual cash expenses, $1,000[e]	95.16	97.72	101.74	100.05	104.63	109.49
Average annual net cash income, $1,000[f]	50.94	26.03	44.36	46.05	19.12	14.00
Net cash income, $1,000:[g]						
1994	51.55	51.55	51.55	51.55	51.55	51.55
1995	61.42	50.48	58.22	59.84	47.29	45.71
1996	65.41	43.11	59.02	62.15	36.72	33.46
1997	62.03	29.37	53.44	57.05	20.67	15.62
1098	57.07	22.35	48.25	50.36	13.00	6.01
1999	36.26	0.18	27.03	27.68	-9.93	-18.69
2000	22.85	-14.74	12.97	13.71	-26.13	-35.77
Probability of survival, %[h]	100	96	100	100	93	90
Probability of success, %[i]	75	35	68	70	29	17
Probability of lower real equity, %[j]	55	87	63	62	96	100

[a] Percentage change in real ner worth over the simulation period 1994-2000.
[b] Discounted value of net worth in the last year simulated.
[c] Average ratio of returns to assets over all solvent years.
[d] Total cash receipts from livestock and government payments.
[e] Total cash receipts for livestock production, including interest costs and fixed cash costs; excludes depreciation.
[f] Total cash receipts minus total cash expenses; excludes family living expenses, principal payments and costs to replace capital assets.
[g] Present value of net cash income for each year of simulation.
[h] Probability that the ranch will remain solvent (equity-to-asset ratio greater than 15%) during the simulation period.
[i] Chance that the farm will earn a return on initial equity greater than 5.76%.
[j] Probability of lower equity of last year when compared to year 1 of simulation.

greater than 20% will severely compromise the ability of Colorado sheep ranches to stay in business beyond 1996. This will be especially true for operations with high operating costs and/or low production efficiencies.

This analysis assumed that lamb prices will be driven by the same market forces as in the past. It is possible that 1995-1998 lamb prices will materialize at lower levels than those forecasted. Consequently, lower lamb prices will drive net cash income to even lower levels than those projected in this study. On the other hand, a decline in ewe inventory numbers as a result of some operations exiting the industry may reduce supplies sufficiently to keep prices from declining beyond 1998. Furthermore, lamb prices will remain sensitive to the volume of imported lamb and world wool markets. Total imports may increase under the provisions of the North American Free Trade Agreement (NAFTA) and the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). Given the uncertain effect of these agreements on domestic and global lamb and wool prices, sheep operations in Colorado will need to take a closer look at maximizing production efficiency, reducing operating costs, restructuring debt and diversifying their enterprises if they are to enhance their chances of survival.

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Figure 1. Projected annual net cash income of the representative Colorado sheep ranch for all cases analyzed at 20% debt.

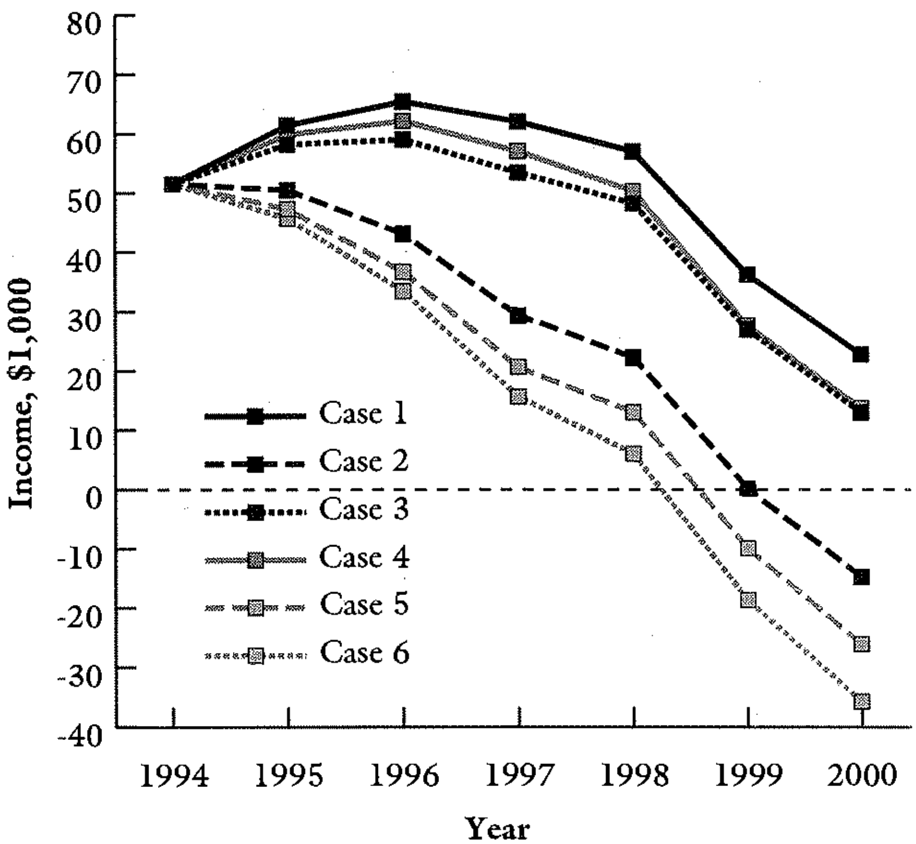

Figure 2. Probability of success of the representative Colorado sheep ranch for all cases analyzed at 20% debt.

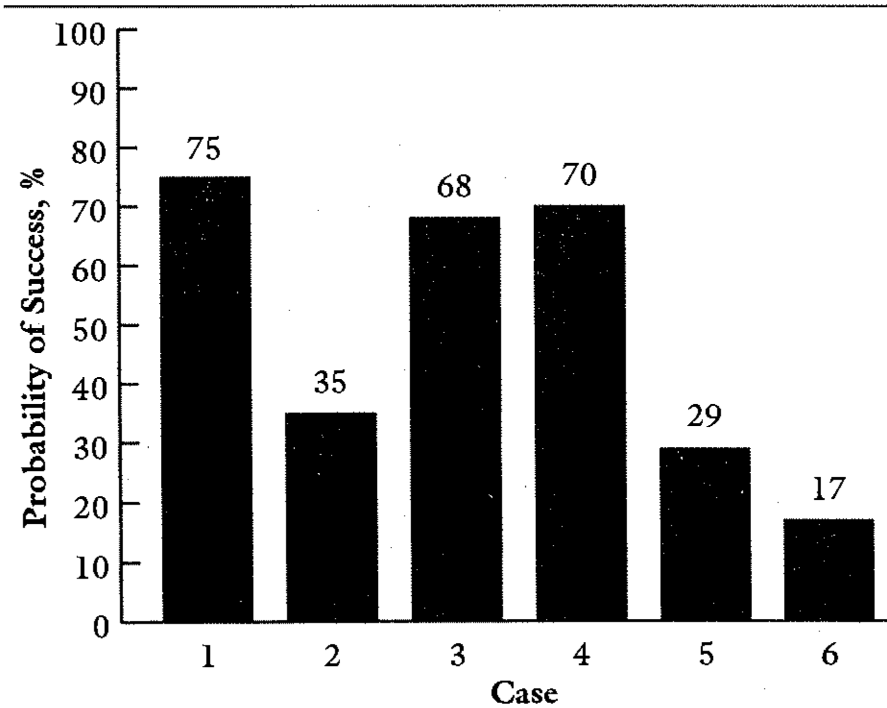

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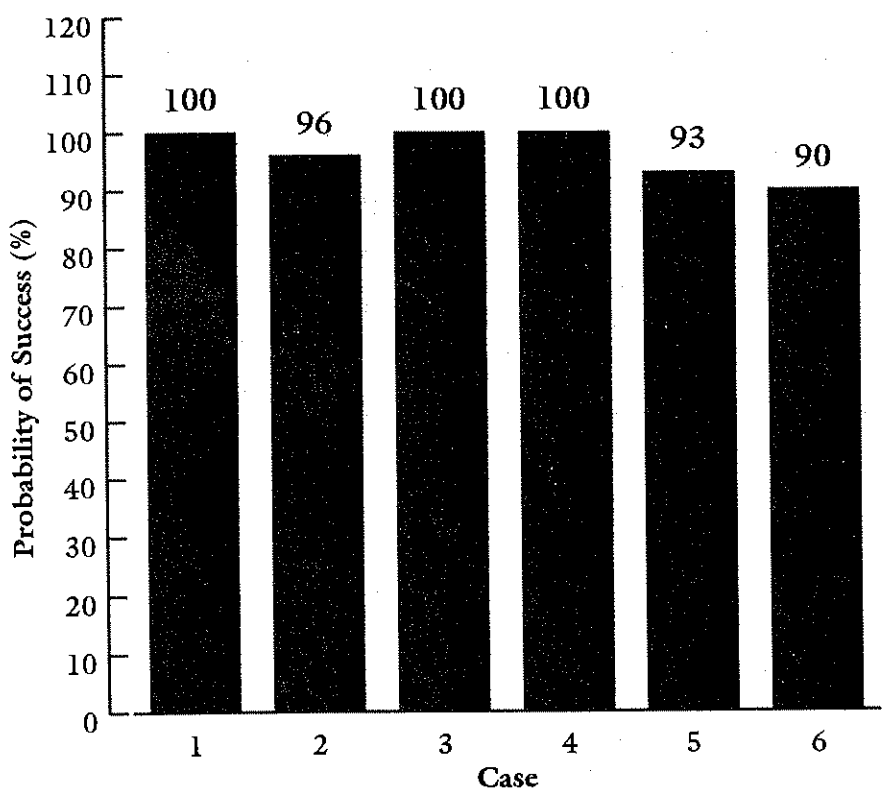
Figure 3. Probability of survival of the representative Colorado sheep ranch for all cases analyzed at 20% debt.



Consumer Perceptions of Lamb Compared with Other Meats

Clement E. Ward[1], Arnella Trent[2] and Jacky L. Hildebrand[3]

Summary

This article describes how surveyed consumers in Tulsa, OK, ranked lamb compared with other meats for several meat characteristics. Three thousand households were surveyed, with 600 returning usable surveys. Respondents were divided into groups based on frequency of meat purchases. Three hundred twenty-seven lamb consumers were divided into groups based on when and where they last ate lamb.

Consumers were asked to evaluate seven meats: beef, chicken, fish, lamb, pork, turkey and veal. Consumers rated meats for several meat attributes: taste, cholesterol, nutritional content, economic value, fat, convenience/ease in cooking and overall preference.

Based on respondents' perceptions, lamb has a consumer image problem. The lamb industry faces an uphill battle to increase demand for lamb. Respondent consumers ranked lamb last among seven meats for taste, convenience/ease in cooking and overall preference. Lamb ranked sixth for nutritional content and fifth, above other red meats, for cholesterol and fat content.

Three-fourths of the consumers who last ate lamb during the year prior to completing the survey had last eaten lamb in a restaurant. Both for home and restaurant consumption of lamb, there was a tendency for lamb consumers to be better educated, older and have higher incomes.

Factors most important to consumers when purchasing meat were taste, quality and color/appearance. Factors most important in increasing lamb consumption were high quality and consistent quality. Results suggest lamb products must be consistently high quality and good tasting. Product appearance, fat content and price are also important.

Key words: lamb, meat, marketing, consumer perceptions, consumer attitudes.

Introduction

Per capita lamb consumption on a retail-weight basis has averaged about 1.3 to 1.4 pounds annually since 1979 (Economic Research Service, 1994). Demand for lamb is difficult to analyze due to data limitations, but since 1970, research has shown that demand for lamb has declined significantly (Purcell, 1989; Texas A&M Market Research Center [TAMRC], 1991). The demand curve appears to have shifted downward and to the left, indicating a decrease in demand. The retail price of lamb influenced per capita lamb consumption as expected. However, other traditional economic forces, such as per capita income and prices for competing meats, were found to be less important than expected in explaining the variation in annual per capita consumption. Time-related variables were also important, but they may be capturing attitudinal and behavioral changes of lamb consumers over time.

As noted, the retail price of lamb was found to be an important factor when consumers purchase lamb. The higher the price, the smaller the quantity consumers buy; and the lower the price, the larger the quantity they buy. Economic value, as measured by retail lamb prices, has been problematic for lamb compared with other meats. Consumers often view lamb as a high-priced item. In fact, relative to other red meats, retail lamb prices have increased more than other meats when viewed as percentage of farm-level prices (Purcell, 1989).

Research supports the contention that changes in consumer tastes and preferences are another possible explanation for the decline in lamb demand (Buse et al., 1989). Purcell (1989) argued that in 1979 or 1980, demand for beef and pork started a long-term decline because of increasing consumer concerns about fat and

[1] Professor and Extension Economist, Department of Agricultural Economics, Oklahoma State University, Stillwater, OK 74078.

[2] Former Graduate Assistant, Department of Agricultural Economics, Oklahoma State University, Stillwater, OK 74078.

[3] Former Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, Stillwater, OK 74078.

cholesterol and increasing demands for consistent quality and convenience in preparation. Research confirms consumers' concerns about diet and health relationships, especially for red meats (Burke Marketing Research, 1987; Purcell, 1993). Food processors and marketers recognize the relationships between changing lifestyles and consumer attitudes and changes in food purchases. Consumer attitudes affect their eating habits; and eating habits, in turn, affect demand for the foods purchased (Capps et al., 1988; Menkhaus et al., 1988; McNaughton et al., 1990). As a result, consumer attitudes and perceptions need to be monitored and understood.

Market demographics and consumer lifestyles are also important in determining consumer demand for meats (Buse et al., 1989), and in particular for lamb (TAMRC, 1991). Better-educated and higher-income consumers worry less about price than about factors that affect quality and acceptability. As consumers become better educated and more informed, they are more inclined to think about what they eat and how it fits into their lifestyle. These consumers are more willing to compromise taste for a product that is perceived to be more healthy (Capps et al., 1988). Thus, nutrition, fat level and cholesterol are important factors affecting meat consumption. On the other hand, non-health factors such as availability, convenience and ease of preparation also affect consumers' meat purchases.

This article describes how meat consumers in one metropolitan area ranked lamb compared with other meats for several meat characteristics: taste, cholesterol, nutritional content, economic value, fat, convenience/ease in cooking and overall preference. Lamb consumers were divided into groups based on when and where they last ate lamb. The demographic profile of lamb consumers is reported and factors which influence increased lamb consumption in the future were analyzed.

Materials and Methods

A market research firm provided names for randomly selected consumer households in the Tulsa metropolitan area that were believed to represent the general population. A survey questionnaire was mailed to 3,000 households in May of 1993. Completed surveys were received from 600 households, a 20% response rate. Respondent data were entered into a Statistical Analysis System (SAS) data set for analysis.

Respondents who purchased meat for household consumption were divided into four groups based on the frequency of eating meat. Those groups and group names used in this article are shown in Table 1.

Table 1 also summarizes the number of respondents in each group. Three groups had nearly an equal number of respondents. Only the Light Users group had considerably fewer respondents than the other three groups.

Respondents who had eaten lamb also were divided into four groups based on when and where they last ate lamb. Those groups and group names used in this article are shown in Table 2.

Table 2 also summarizes the number of respondents in each group. Fewer respondents consumed lamb within the past year (from the time they completed the survey) than those that had consumed lamb in previous years. Of those respondents who ate lamb within the past year, three times as many last ate lamb in a restaurant compared with last eating lamb at home.

Duncan's multiple range statistic was estimated to test whether or not there were significant differences among mean responses for each group (Fryer, 1966). Test results at the 95% confidence level are reported in this article.

Table 1. Distribution of respondents by frequency of household meat consumption.

Group name	Frequency of meat consumption	Respondents: Number	Respondents: Percent of total
Light users	2 times or less per week	81	13.5
Moderately light users	3 to 4 times per week	174	29.0
Moderately heavy users	5 to 6 times per week	175	29.2
Heavy users	7 times or more per week	170	28.3
Total	—	**600**	**100.0**

Table 2. Distribution of respondents by when and where they last ate lamb.

Group name	Last ate lamb: When	Last ate lamb: Where	Respondents: Number	Respondents: Percent of total
Current year/home users	Less than 1 year ago	Home	31	9.5
Current year/restaurant users	Less than 1 year ago	Restaurant	97	29.7
Previous year/home users	More than 1 year ago	Home	116	35.5
Previous year/restaurant users	More than 1 year ago	Restaurant	83	25.4
Total	—	—	**327**	**100.1**[a]

[a] Total does not equal 100 due to rounding.

Results and Discussion

Lamb versus Other Meats

One objective of this study was to determine how consumers rated lamb versus other meats for several meat characteristics and for substitutability. Consumers were asked to evaluate seven meats: beef, chicken, fish, lamb, pork, turkey and veal. Consumers rated the seven meats for each of the meat attributes evaluated: taste, cholesterol, nutritional content, economic value, fat, convenience/ease in cooking and overall preference. Results are summarized in Table 3. The focus of this discussion is on lamb; for a more general discussion, see Ward and Hildebrand (1995).

Taste. Consumers ranked meats based on taste in the following order from highest taste to lowest: beef, chicken, pork, turkey, fish, veal and lamb. There was no significant difference in perceptions among consumer groups based on their frequency of meat consumption for chicken, turkey, fish, veal and lamb.

Cholesterol level. For years, consumers read and heard reports linking high cholesterol with health problems, especially heart disease. Recommendations were usually to reduce consumption of red meats. Diet/health concerns are believed to be a major cause of reduced per capita consumption of red meats. Consumers in this study ranked meats lower on average based on cholesterol level than they did based on taste. Consumers ranked meats in the following order from lowest cholesterol to highest: fish, turkey, chicken, veal, lamb, pork and beef. All four red meats rated lower than did the three other meats. There was a significant difference among meat-consuming groups only for fish. For the other meats, consumer perceptions were very consistent and not affected by the frequency of meat consumption.

Nutritional content. Consumers rated the seven meats in a relatively narrow band of responses. Means among meats differed from the highest nutritional ranking of 5.19 for fish to the lowest of 4.37 for pork. Consumer rankings of meats from highest nutritional content to lowest were: fish, beef, chicken, turkey, veal, lamb and pork. Consumer ratings among meat-consumption groups differed more than for previously discussed traits. There was no significant difference among the meat-consuming groups in their ratings of the nutritional content of fish, the highest rated meat. For nearly all other meats, nutritional content ratings increased as meat consumption increased. Consumers either consume more meat because of its nutritional content or rate its nutritional content high to justify higher meat consumption. Nutritional content ratings differed most for beef and pork. In both cases, light users rated the nutritional content significantly lower than each of the other meat-consuming groups.

Economic value. Consumers rated the seven meats in the following order from highest to lowest on their perception of economic value: chicken, turkey, beef, pork, fish, veal and lamb. From 1970 to 1993, annual per capita consumption of broiler chicken (on a retail weight basis) increased from 36.9 to 68.3 pounds (Economic Research Service, 1994). Based on this survey and previous market research, one major explanation for the increase in poultry consumption is because consumers consider poultry to be an economical purchase. Consumer rankings of economic value were consistent across meat-consuming groups for three of the four highest-ranking meats and the second-lowest ranking meat. For the other three meats (beef, fish, lamb) significant differences were found between some consumer groups. For lamb, heavy and moderately heavy users rated its economic value lower than did light and moderately light users.

Fat level. Consumers constantly hear and read that Americans consume too much fat and that fat leads to obesity and such health-related problems as heart disease, high blood pressure, stroke and even cancer. Livestock and meat organizations, including the sheep and lamb industry (TAMRC, 1991), recognize the problem of excessive fat. Efforts to reduce fat

Table 3. Consumer perception of lamb and other meats, by selected characteristics.

	Mean response and rank[a]						
Characteristic	Beef	Chicken	Fish	Lamb	Pork	Turkey	Veal
Taste[b] (high to low)	5.56 (1)	5.32 (2)	4.60 (5)	3.38 (7)	4.92 (3)	4.85 (4)	4.16 (6)
Cholesterol level[c] (low to high)	4.88 (7)	2.36 (3)	1.78 (1)	4.02 (5)	4.81 (6)	2.17 (2)	3.70 (4)
Nutritional content[b] (high to low)	5.07 (2)	5.06 (3)	5.19 (1)	4.42 (6)	4.37 (7)	4.94 (4)	4.53 (5)
Economic value[b] (high to low)	4.19 (3)	4.71 (1)	3.97 (5)	3.21 (7)	3.99 (4)	4.51 (2)	3.22 (6)
Level of fat[c] (low to high)	4.82 (6)	2.51 (3)	1.70 (1)	4.03 (5)	4.88 (7)	2.18 (2)	3.54 (4)
Convenience/ ease in cooking[b] (high to low)	5.44 (1)	5.27 (2)	4.58 (5)	3.38 (7)	4.78 (3)	4.62 (4)	4.04 (6)
Overall preference[b] (high to low)	5.17 (1)	5.16 (2)	4.29 (4)	2.34 (7)	4.17 (5)	4.35 (3)	2.85 (6)

[a] Rank among meats for each characteristic is in parentheses.
[b] Response scale was 1 = high to 6 = low.
[c] Response scale was 1 = low to 6 = high.

content of meats have included more closely trimming meats to reduce the amount of fat presented to consumers at the meat case and attempting to put less fat on animals prior to slaughter. The move to mandatory U.S. Department of Agriculture (USDA) yield grading of slaughter lambs when lambs are USDA quality graded in 1992 was a move to reduce the number of overfinished lambs.

Ratings of meat based on fat level were lower than for most other meat attributes. Consumers rated the seven meats, in order from leanest to fattest: fish, turkey, chicken, veal, lamb, beef and pork. Fish and poultry were rated lowest in fat and the four red meats rated highest in fat content. Consumer ratings for fat among consumer groups was very consistent. The only meat for which consumer perceptions differed significantly was fish.

Convenience/ease in cooking. Many people have speculated that per capita red meat consumption has declined and per capita poultry consumption has increased because of the proliferation of convenient, microwaveable poultry products in the supermarket. Time is precious and limited for busy dual-income families and many are willing and able to pay higher prices for convenient-to-prepare food items. Statements are made that if it takes more than 30 minutes to prepare, consumers will shy away from it and look for more convenient products. Consumers rated the seven meats in order of most to least convenient or easy to prepare as follows: beef, chicken, pork, turkey, fish, veal and lamb. Consumers rated convenience and ease of preparation consistently among meat-consuming groups for chicken, turkey, fish and lamb.

Overall preference. Overall, consumers clearly rated beef and chicken highest (means of 5.17 and 5.16, respectively). Next, in a middle group, were turkey, fish and pork (means of 4.35, 4.29 and 4.17, respectively). Consumers clearly least preferred veal and lamb (means of 2.85 and 2.34, respectively). Consumer preferences were consistent among meat-consuming groups for one of the top-rated meats, chicken, and the two lowest-rated meats, veal and lamb.

Consumers were also asked to rate how similar or dissimilar all the possible pairs of seven meats were. Results for lamb are shown in Table 4. Closest substitutes among all meat pairs were chicken and turkey, with a mean of 7.58. Next closest were beef and veal (mean of 6.28). There was a significant difference between the beef-veal mean and the next closest substitute pair, 4.58 for chicken and fish. Consumers rated beef and fish the most dissimilar (mean of 2.02). Next most dissimilar pairs were beef and chicken (mean of 2.32) and fish and pork (mean of 2.33).

As was expected, the closest perceived substitute for lamb was veal; followed by beef and pork, the other two red meats. Turkey, chicken and fish were not seen as close substitutes. While lamb marketers cannot ignore the lesser-perceived substitutes, attention needs to focus on veal, followed by beef and pork. Lamb's closest perceived substitute, veal, is struggling with an image problem resulting from production methods related to crate-raised calves. Any reduction in per capita consumption of veal may be captured by lamb with proper market planning and positioning.

Table 4. Consumer perception of meat pairs.

	Mean response[a]						
	Beef	Chicken	Fish	Lamb	Pork	Turkey	Veal
Beef	—	2.32	2.02	3.97	4.48	2.47	6.28
Chicken	—	—	4.58	2.98	3.33	7.58	3.50
Fish	—	—	—	2.45	2.33	3.69	2.92
Lamb	—	—	—	—	3.81	3.01	4.52
Pork	—	—	—	—	—	2.88	3.98
Turkey	—	—	—	—	—	—	3.51
Veal	—	—	—	—	—	—	—

[a] Response scale for each pair of meats (i.e., beef vs. chicken) was 1 = Very Dissimilar to 6 = Very Similar.

Meat consuming groups rated pairs of means quite consistently. Significant differences among meat-consuming groups were found only for 3 of the 21 possible pairs. All three pairs involved fish: fish-pork, fish-lamb and fish-turkey. One possible explanation involves the wide range of fish and seafood products which consumers might have had in mind when answering this question, from fresh-water fish, to processed fish, to salt-water fish and shellfish.

Lamb Consumer Demographics

A second objective of this study was to examine the demographics of lamb consumers and to understand better the factors lamb consumers consider important in purchasing lamb and potentially increasing lamb consumption. In the following discussion, the focus will be on the two current-year lamb consumer groups (current-year/home users and current-year/restaurant users) based on the assumption that they are the most likely lamb-consumer groups to eat lamb again. However, it is important not to ignore the two previous-year groups (previous-year/home users and previous-year/restaurant users). They ate lamb sometime in the past but not recently. Previous market research found similar results (Walker Research and Analysis, 1988, 1989). About 50% of the population has eaten lamb at some time but their experience must not have been positive enough to entice them to continue eating lamb.

Among the current-year groups, about three-fourths of respondents last ate lamb in a restaurant, and the last lamb consumption experience for all demographic categories of respondents was a restaurant. This suggests that their restaurant experience is very important. If it is positive, two subsequent behaviors may be observed: 1) repeat restaurant purchases of lamb;

and 2) possible retail purchase of lamb for home consumption with family and/or guests. High-quality, correctly prepared lamb needs to reach restaurant patrons. This survey supports previous recommendations that the lamb industry needs to focus on marketing consistent, high-quality lamb to restaurants (TAMRC, 1991).

Of the two previous-year groups, a higher percentage last ate lamb at home than at a restaurant. However, that differed somewhat for specific demographic subgroups.

The following highlights information in Table 5 for each demographic category.

Gender. More men than women ate lamb within the past year. However, considering where they last ate lamb, the percentage of men and women were nearly the same.

Age. The number of respondents in each age category increased for the two current-year groups. Older consumers were those most likely to have eaten lamb within the past year. The TAMRC (1991) study noted that food consumption data indicate consumer expenditures for meat increase with age. Targeting senior citizens for lamb consumption should be considered, given the rapid population growth in older age groups in the U.S. One of many unanswered questions is whether older Americans have eaten lamb in the past year because they ate lamb more when they were younger or whether they first tried lamb when they were older.

Education. The highest percentage of lamb consumers, both for the current-year and previous-year groups, have some college education or have earned one or more college degrees.

Household income. A higher percentage of current-year lamb consumers were in the annual household income range of $30,000 to $49,999 than in any single income group. Among the highest income group, a higher percentage last ate lamb at a restaurant. In general, as incomes increased, the percentage of current-year/restaurant users increased. Food consumption data indicate that expenditures on meat increase with increased incomes (TAMRC, 1991). Restaurants may be targeted with more expensive, higher-quality cuts of lamb because of a potentially higher demand for them from higher-income patrons.

Marital status. About three-fourths of current-year respondents were married.

Race. For both current-year consumer groups, nearly the same percentage of respondents were white.

Table 5. Demographic profile of lamb consumers, by when and where they last ate lamb.

Demographic category	Last ate lamb: Less than 1 year ago		More than 1 year ago	
	Home	Restaurant	Home	Restaurant
Gender:				
Male	17	58	74	41
Female	13	40	42	43
Age:				
Less than 35	1	15	14	6
35-44	6	17	24	8
45-54	7	18	20	18
55-64	8	23	19	18
65 or more	9	25	38	34
Education:				
High School	7	15	4	23
Some College	7	29	25	33
Bachelor Degree	6	32	35	16
Graduate Degree	10	22	51	12
Household income:				
Less than $30,000	9	17	17	30
$30,000-49,999	9	31	27	27
$50,000-69,999	7	22	26	13
$70,000 or more	4	20	42	6
Marital status:				
Married	23	74	88	53
Other	7	24	27	30
Race:				
White	28	91	112	76
Other	2	7	4	6
Occupation:				
White collar	10	41	54	12
Blue collar	5	6	4	9
Other	3	7	9	12
Retired	9	28	34	41
Self-employed	3	13	12	7
Government	0	2	3	2
Household size:				
1	4	18	26	18
2	19	47	54	37
3	8	28	30	19
4 or more	0	3	5	7
Religion:				
Christian	23	91	107	73
Other	6	7	8	9

Occupation. One-third of current-year lamb consumers who last ate lamb at home within the past year were white collar workers. A higher percentage of white collar workers (42.2%) last ate lamb in a restaurant within the past year. The next highest respondent group consisted of retirees. Again, targeting older Americans may be a potential marketing strategy for lamb.

Household size. For both current-year groups, the household size with the most respondents was two, usually a husband and wife.

Religion. A higher percentage of Christian respondents reported last eating lamb in a restaurant than at home (92.8% vs. 79.3%, respectively). Those who practice a religion which may promote or allow more lamb consumption may be more likely to eat lamb at home because of the lack of restaurants which prepare lamb according to religious standards.

Factors Affecting Increased Lamb Consumption

Lamb consumers were asked to rate factors which influence meat purchases generally and factors which influence lamb purchases specifically. Results are given in Tables 6 and 7.

Table 6. Importance of selected factors to lamb consumers in purchasing meat by when and where they last ate lamb.

	Mean response and Duncan test results[a]			
	Less than 1 year ago		More than 1 year ago	
Factors	Home	Restaurant	Home	Restaurant
Taste	5.87[b]	5.72[b]	5.78[b]	5.84[b]
Packaging	3.43[c]	3.63[c]	3.53[c]	4.16[b]
Nutritional content	4.97[b]	4.74[b]	4.86[b]	4.95[b]
Color/appearance	5.32[b]	5.43[b]	5.20[b]	5.37[b]
Economic value	5.26[b]	4.70[c,d]	4.59[d]	5.05[bc]
Variety in meat preparation	4.71[b]	4.39[b]	4.43[b]	4.78[b]
Level of cholesterol	4.90[b]	4.50[b]	4.66[b]	4.80[b]
Tenderness	5.45[b,c]	5.30[c]	5.22[c]	5.65[b]
Convenience/ease in cooking	4.97[b,c]	4.99[b,c]	4.66[c]	5.24[b]
Quality	5.68[b]	5.64[b]	5.61[b]	5.71[b]
Level of fat	5.23[b]	4.82[b]	4.84[b]	5.14[b]

[a] Response scale was 1 = Not at All Important to 6 = Extremely Important.
[b,c,d] Means with the same letter for the same factor were not statistically significantly different at the 0.05 level.

Table 7. Importance of selected factors in increasing lamb consumption by when and where lamb consumers last ate lamb.

	Mean response and Duncan test results[a]			
	Less than 1 year ago		More than 1 year ago	
Factors	Home	Restaurant	Home	Restaurant
Lower price	4.97[b]	4.19[c]	4.41[b,c]	4.86[b]
Availability	5.03[b]	4.41[c]	4.67[b,c]	4.74[b,c]
Nutritional labeling	4.00[b]	4.08[b]	3.81[b]	3.84[b]
Less fat	4.73[b]	4.22[b]	4.29[b]	4.48[b]
Cooking instructions	3.55[c]	4.45[b]	3.52[c]	4.49[b]
Recipes	3.83[c]	4.30[b,c]	3.62[c]	4.53[b]
High quality	5.23[b]	4.98[b]	5.20[b]	5.25[b]
Consistent quality	5.17[b]	5.00[b]	5.17[b]	5.25[b]

[a] Response scale was 1 = Not at all Important to 6 = Extremely Important.
[b,c] Means with the same letter for the same factor were not statistically significantly different at the 0.05 level.

Several factors affect meat purchases. Respondents rated the factors included in this study in the following order from highest to lowest: taste, quality, color/appearance, tenderness, convenience/ease in cooking, level of fat, economic value, nutritional content, level of cholesterol, variety in meat preparation and packaging (Table 6). Responses were consistent among lamb-consuming groups based on when and where they last ate lamb for each of the three highest-rated factors (taste, quality, color/appearance), along with level of fat and three of the lowest rated factors (nutritional content, level of cholesterol, variety in meat preparation).

Significant differences were found for tenderness, convenience/ease in cooking, economic value and packaging. However, differences were not consistent among lamb consuming groups.

What will cause lamb consumers to increase lamb consumption? Several factors were rated by respondents (Table 7). Factors listed in order from most important to least important were: high quality, consistent quality, availability, lower price, less fat, recipes, cooking instructions and nutritional labeling. Lamb-consuming groups rated the two most important factors consistently (high quality, consistent quality) as well as less fat and nutritional labeling. Results further emphasize the need to produce consistently high-quality, lean lamb products as efficiently as possible.

Differences among lamb-consuming groups were found for other factors (availability, lower price, recipes and cooking instructions). Availability was rated higher by current-year/home users than by current-year/restaurant users. Lamb consumers may know which restaurants carry lamb but perhaps consumers are unaware of which retail stores carry lamb, or those stores do not have a consistent supply of desired cuts. Lower price was also more important to current-year/home users than current-year/restaurant users. Persons buying lamb in restaurants may expect to pay higher prices than in retail stores. In effect, dining out may involve both eating pleasure and entertainment. Surprisingly, current-year/restaurant users rated cooking instructions as more important than current-year/home users. If their restaurant experience with lamb is positive, they need cooking instructions prior to purchasing lamb for home use.

Conclusions

This study surveyed consumers from a single metropolitan area. Ideally, such a survey should be replicated for several metropolitan areas geographically distributed throughout the U.S. Therefore, results must be placed in proper perspective. If respondents are representative, then the following inferences can be drawn.

Lamb has a consumer image problem. Respondent consumers ranked lamb last among seven meats for taste, economic value, convenience/ease in cooking and overall preference. Lamb ranked sixth for nutritional content and fifth for cholesterol and fat content.

Three-fourths of the consumers who last ate lamb during the year prior to completing the survey had last eaten lamb in a restaurant. Both for home and restaurant consumption of lamb, there was a tendency for lamb consumers to be better educated, older and have higher incomes.

Factors most important to consumers when purchasing meat were taste, quality and color/appearance. Factors most important for increasing lamb consumption were high quality and consistent quality. Results suggest that the lamb industry must improve lamb products. Products must be consistently high quality and good tasting. Product appearance and nutritional content are also important. Price is important and efforts must be made to increase the economic value of lamb products presented to consumers.

Clearly these survey results, which confirm in several ways previous market research results, indicate that the lamb industry faces an uphill battle to increase demand for lamb. Some consumer segments are less apt to consume lamb than others. Therefore, limited promotional dollars must target specific market segments; and lamb products must be tailored to those market segments. Results suggest more emphasis needs to be placed on penetrating the food service sector, especially restaurants, with high-quality, uniform lamb products.

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Automatic Image Analysis System for Objective Measurement of Animal Fibers[1,2]

K. Qi[3], C.J. Lupton[3,4], F.A. Pfeiffer[3], D.L. Minikhiem[3], N.S. Kumar[5] and A.D. Whittaker[5]

Summary

The imaging system at the Texas Agricultural Experiment Station (TAES), San Angelo, TX, originally developed for measuring fiber diameter distributions only, was upgraded to a general-purpose image analyzer for quantifying numerous characteristics of animal fibers. By providing measurements of multiple traits in a single instrument, it is anticipated that the cost of measuring fibers can be reduced. A series of algorithms was developed for fiber image enhancement, fiber recognition and subsequent measurement of: 1) average fiber diameter (AFD) and standard deviation (SD); 2) average staple length (ASL) and its SD; 3) mechanical yield of cashmere; 4) medullation in mohair; 5) color of scoured fibers; and 6) colored fiber content. Results produced by the new system were compared with those from standard methods for AFD ($r = 0.994$, $P < 0.0001$), ASL ($r = 0.998$, $P < 0.01$), mechanical yield of cashmere ($r = 0.912$, $P < 0.0001$) and medullation in mohair ($r = 0.414$, $P > 0.20$). For measuring color of scoured white animal fibers, the imaging system was programmed to be a colorimeter equivalent. As a result, in Commission Internationale de l'Eclairage's (CIE) XYZ Color Space, the r values between X, between Y and between Z of measurements made with our system versus a colorimeter for 33 scoured U.S. wools were 0.950 ($P < 0.0001$), 0.940 ($P < 0.0001$) and 0.926 ($P < 0.0001$), respectively. The program for analyzing black and colored fibers in predominantly white samples distinguishes dark pigmented fibers from lighter-stained, yellow fibers. Preliminary data show that the program has a high speed of measurement with reasonable accuracy. All the developed programs except the one for measuring medullation provide satisfactory results. Further refinement of the medullation program is required. Commercialization of this versatile imaging system is under investigation.

Key words: image analysis, automation, animal fiber characterization.

Introduction

Since 1988, researchers at the Wool and Mohair Research Laboratory of the Texas Agricultural Experiment Station (TAES) in San Angelo, TX, have used an Image Analyzing System (Analytical Imaging Concepts, Irvine, CA) for measuring fiber diameter distributions of animal fibers. In 1992, an Optical Fibre Diameter Analyser (OFDA) was obtained (BSC Electronics Pty. Ltd., Attadale, Australia) for evaluation (Qi et al., 1994a). The aforementioned two instruments are limited in that they are only programmed to analyze black and white images and output average fiber diameter (AFD) and variability of fiber diameter (SD, CV). Source codes for the programs for these two instruments were retained by the manufacturers for commercial reasons. Consequently, modification of the programs is not possible by anyone except the manufacturers. Recently, a new image-capture board and a charge-coupled device (CCD) color video camera were added to the system with several compatible programming tools. These components provided the capability of developing programs for measuring other fiber characteristics. The economical importance of these fiber

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[3] Texas Agricultural Experiment Station, 7887 North Highway 87, San Angelo, TX 76901.

[4] To whom correspondence should be addressed.

[5] Department of Agricultural Engineering, Texas A&M University, College Station, TX 77843.

characteristics was summarized previously (Lupton, 1992; Qi et al., 1994a,b,c,d). Thus, research objectives were to: 1) develop software and apparatus for using automatic image analysis technology for measuring AFD and its SD, ASL and its SD, mechanical yield of cashmere, medullation in mohair, color of scoured fleeces and colored fiber content; and 2) evaluate the developed fiber image analysis software for application in the sheep and goat industries and for further commercialization.

Materials and Methods

The TAES Image Analysis System

Hardware components. The TAES Automatic Image Analysis System consists of: an analytical microscope (Nikon SCU-1) with a video adapter and a programmable stage (Nikon Scanning Stage); a CCD black-and-white camera (Javelin JE2362) and a CCD color video camera (JVC TK-1070U) with a zoom lens (H6X12.5R, Fujinon-TV), both of which can be fitted to the microscope or to a camera-stand when macro rather than micro views are required; a Targa-compatible display monitor (Sony Trinitron PVM-1271Q); a Truevision Targa+ ISA (64) Graphics Engine (Targa Imaging Board; Truevision, Inc., Indianapolis, IN); an IBM-compatible computer (Comtrade, Inc., Industry City, CA); an HP LaserJet III laser printer; and sample preparation and mounting devices.

The CCD camera captures fiber images and converts them into electric signals. These electric signals are then fed out to the Targa Imaging Board for digitization. The processing system is a 486DX/33MHz microcomputer with 16 megabytes of RAM, 180 kilobytes of cache memory and a 250-megabyte hard disk.

Program tools. The program tools used in the TAES Image Analysis System include Microsoft Visual C++ (version 1.5), Microsoft Windows Software Development Kit (Windows SDK; version 3.1) and Truevision Targa Compatible Toolkit (release 1.0).

Algorithms for Quick Capture of Fiber Image, and Subsequent Segmentation, Recognition and Measurement

Automation for continuous, real-time image capture and processing. In programming the TAES Image Analysis System for measuring AFD and its SD, medullation in mohair and colored fiber content, it was essential that the system be automated in order to continuously capture and analyze fiber images. This was necessary to ensure that enough fibers be analyzed to achieve certain specified precision (American Society for Testing and Materials [ASTM], 1993a,b,c) in a relatively short time. Thus the analytical microscope was fitted with a programmable stage (Nikon Scanning Stage) which was linked to a serial port and controlled by custom-designed programs. The capability was developed to scan and analyze 10,000 fibers in five minutes and the system was therefore named "The TAES Automatic Image Analysis System."

Algorithm for measuring fiber diameter. Recognition and distinguishing individual fibers from fibers lying side-by-side and from contaminating debris and dust were accomplished through a series of fiber image tests and model matching (Figure 1). In summary, a program was developed to distinguish fibers using specially designed masks (Kumar, 1995). The fiber images are considered to have straight edges (linearity test). For a fiber image both edges should parallel each other (symmetric test). Upon finishing linearity and symmetric tests, a conclusion was made regarding the image under consideration being a fiber image versus a contaminant image. Then a series of 18 fiber image masks with different orientations (10 degrees apart on consecutive masks) was fitted to the recognized fiber image to identify the best match (angle test). Finally, the diameter for the fiber image was calculated. This procedure was repeated several thousands of times in order to get an accurate estimate of AFD and SD for a sample. The program-measured diameters (in pixels) for a set of standard Interwool-labs IH wool tops (Qi et al., 1994a) were compared with the results obtained using the standard method (ASTM, 1993a) to evaluate the accuracy and precision of this program.

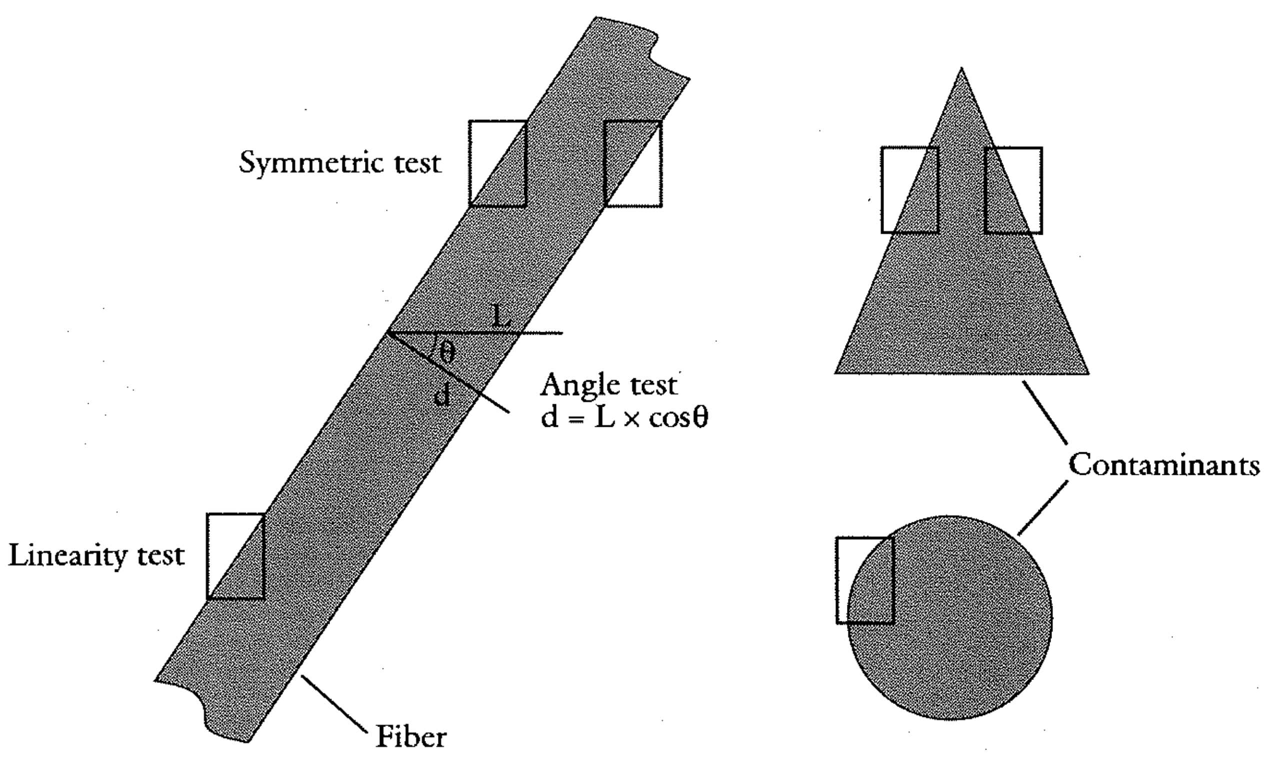
Algorithm for measuring wool staple length. Wool staples are relatively uniform in shape. Ideally, they may be considered as rectangles (Figure 2). If the staple has a trapezoid shape, one staple can be divided into two parts or two similar staples can be used, and by putting the end of one with the head of another longitudinally, the resulting staple shape becomes rectangular. Thus by measuring total area and perimeter of such a staple with the program, the ASL for each staple can be calculated (Qi et al., 1994d). The staples were placed on a background providing good contrast for easier object recognition (e.g., white staple on black paper). In order to increase the accuracy of measurements, multiple staples (three to six) from the same sample can be measured by the program at one time.

Algorithm for measuring mechanical yield of cashmere. Raw cashmere is a mixture of relatively fine fibers (cashmere down) and coarse guard hairs. Generally, the AFD of cashmere down is in the range of 13 to 19 μm (individual fiber diameters range from 6 to 30 μm), whereas the diameter range of guard hairs is from 31 to 250 μm. Mechanical yield of cashmere refers to the weight of cashmere fibers (less than or equal to 30 μm in fiber diameter) in the scoured, raw cashmere fleece expressed as a percentage (IWTO, 1992). Assuming that densities of cashmere fibers and guard hair fibers are the same, the mechanical yield of cashmere can be estimated using fiber diameter distribution obtained from the histogram of raw cashmere after analyzing for fiber diameter and its distribution in the range 6 to 250 μm (Marschall et al., 1994). These estimated results were compared with results obtained using the standard method (International Wool Textile Organization [IWTO], 1992) which utilizes a Shirley Analyser (Model SDL-102A) to achieve separation of down fibers from guard hairs.

Algorithm for measuring medullation in mohair. Using dark-field illuminating techniques, the opacity of medullated fibers was observed to be different from non-medullated fibers, and opacities of the two different types of medullated fibers (med and kemp) are quantitatively different. The opacities of different fibers were indicated by their pixel values. By selecting the correct threshold levels, a program was developed for distinguishing non-medullated from medullated fibers and also med from kemp fibers (Kumar, 1995). The program counted the numbers of med and kemp fibers and calculated their percentages in the population measured.

Algorithm for measuring color of scoured fibers. To develop a method for measuring color of scoured animal fibers using the TAES Automatic Image Analysis System, a CCD color video camera and a Targa Imaging Board were used to capture and digitize the fiber images in red-green-blue color space (Judd and Wyszecki, 1975). The red-green-blue color space was then converted to device-independent tristimulus values (X, Y, Z) using a cube-root color coordinate system (Glasser et al., 1958; Gentile et al., 1988) pertaining to CIE's illuminant C and 0° observer angle. Fiber samples in the custom-built camera stand were illuminated by four halogen light bulbs (32,000 °K; General Motors, Detroit, MI) to provide uniform illumination at the sample surface. A preliminary program was developed and a series of tests was conducted to: 1) identify the optimum light intensity for color measurement; 2) evaluate the linearity of image digitization of the Targa Imaging Board; 3) standardize the Targa Imaging Board with a proper reference; and 4) assess the glass effect for achieving a more uniform measuring surface with constant density in the wool sample (American Association of Textile Chemists and Colorists, 1990). Finally, the preliminary program was optimized based on the results of these tests (Qi et al., 1994c). The performance of this program for measuring color of scoured animal fibers was compared with a colorimeter (Macbeth 1500, Kollmorgen Instruments Co., New Windsor, NY) using a broad spectrum of wool types representing wools produced throughout the U.S.

Figure 1. The algorithm for fiber recognition and fiber diameter measurement.



To distinguish fibers from contaminating debris and dust, specially designed masks were laid upon the encountered images. Fiber images were considered to have straight edges (linearity test) and parallel edges (symmetric test). After conducting linearity and symmetric tests, a conclusion was drawn regarding the image being tested as to whether it was a fiber or a contaminant. Then a series of 18 fiber image masks with different orientations (10 degrees apart on consecutive masks) was laid upon the recognized fiber image to identify the best match between a fiber image and a specific mask (angle test). Finally, the diameter of the fiber image was calculated. This procedure was repeated thousands of times in order to get an accurate estimate of average fiber diameter for a sample with certain precision.
In the figure, two types of contaminant (circular and triangular) are shown to indicate the difference as tested by this algorithm. This algorithm is incapable of distinguishing real fibers from rectangular contaminants of similar dimensions.

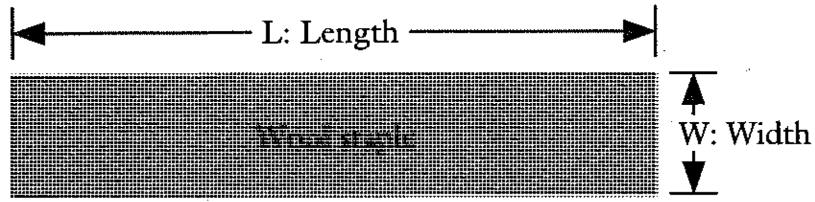
Algorithm for measuring colored fiber content. Recognition of fibers was achieved in a similar manner to that used in the fiber diameter algorithm (Figure 1). The CCD color video camera was used and the Targa Imaging Board was configured to capture and digitize the fiber image in red-green-blue color space (Judd and Wyszecki, 1975). Pigmented and stained fibers were distinguished from white fibers by measuring the color of light transmitted through the fibers. By experimentally establishing proper threshold levels, a program was written to distinguish among white, pigmented and stained/yellow fibers. The program was also capable of calculating percentages for each type of fibers in a particular sample.

This algorithm for measuring colored fiber content in white fleeces is similar to the algorithm for measuring medullation in mohair. Critical differences include: 1) the required illuminating light sources are different (a balanced illumination technique was used to facilitate distinguishing differences in the color of light transmitted through fibers, whereas opacity for medullation was measured using dark field illumination); and 2) measuring colored fiber content in white fleeces requires a color CCD camera and a color imaging board, whereas opacity can be captured and digitized by a black-and-white CCD camera and a black-and-white imaging board.

Results and Discussion

In developing the TAES Automatic Image Analysis System, efforts were focused on developing programs for original, novel applications which are suited for image analysis technology. Furthermore, the intention was to develop as many applications as possible using this single group of instruments. Although some fiber characteristics already have established instruments in the market for their measurement, we still plan to pursue image analysis programs for their measurement because the specialized instruments (usually built for a single application) are very expensive individually and collectively. The cost advantage of a versatile multiple-use system should help to assure

Figure 2. The algorithm for wool staple length measurement.



Algorithm:

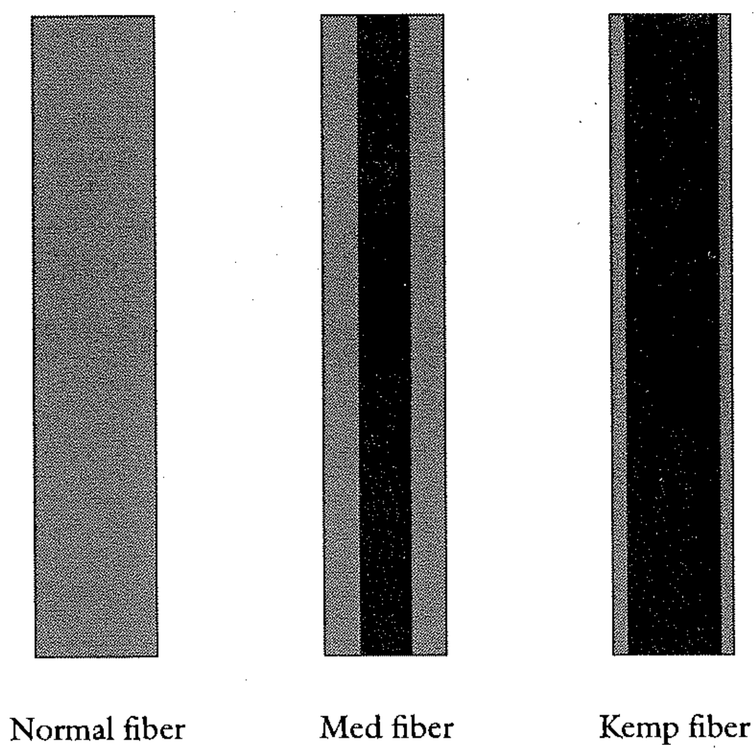
Perimeter: $P = 2 \times (L + W)$

Area: $A = L \times W$

Length: $L = [P + (P^2 - 16 \times A)^{1/2}]/4$

Wool staples are relatively uniform and rectangular in shape. A program was developed to measure area and perimeter of rectangular staples, from which staple length was calculated according to the formula.

Figure 3. The algorithm for medullation measurement.



Using dark field illuminating techniques, the opacity of medullated fibers can be made substantially different from non-medullated fibers, and opacity of med is quantitatively different from that of kemp fibers. The opacities of different fibers were indicated by their pixel values after being digitized by the Targa imaging board. By selecting critical threshold levels, a program was developed for distinguishing non-medullated from medullated fibers and also med from kemp fibers. The program counted all fibers and the numbers of med and kemp fibers and then calculated their percentages in the sample.

commercial success. Table 1 lists the proposed applications and progress to date for fiber characterization using this system.

The program for AFD analysis was shown to be highly accurate and precise (Kumar, 1995). A set of eight Interwoollabs IH tops with known AFD values (17.16 to 37.73 μm) was analyzed using this program (Table 2). The correlation coefficient between the micron values (μm) and the image analysis measurements (pixels) was r = 0.994 (P < 0.0001).

The program for measuring ASL was standardized using a set of five staples ranging from 5 to 15 cm in length. It was then evaluated by comparing results from the image analysis program versus four manual measurements (Table 3). The program-measured lengths and manually-measured lengths were highly correlated (r = 0.998, P < 0.01). This program has potential for eliminating operator errors and increasing speed of measurement.

The program for estimating mechanical yield of cashmere was evaluated by comparing its results with those obtained using the standard procedure. The results from the image analysis program and standard method for 75 raw cashmere fleeces were significantly correlated (r = 0.912, P < 0.0001; Marschall et al., 1994).

The program for analyzing med and kemp fiber contents requires further work. A set of 10 mohair samples was measured (10,000 fibers each) for med and kemp percentages using the standard procedure (ASTM, 1993b) and was then re-analyzed using the image analysis program (Table 4). The r values for med, kemp and total medullation between the results from our system and those obtained with the standard method (ASTM, 1993b) were 0.234 (P > 0.20), 0.325 (P > 0.20) and 0.414 (P > 0.20), respectively. These results are obviously not satisfactory.

The first program for measuring color of scoured fleeces was evaluated using a broad color range of 60 U.S. wools (McColl, 1993; personal communication). Preliminary results indicated that program measurements of color correlated moderately (r = 0.73, P < 0.0001) with results obtained using a colorimeter (Macbeth 1500, Kollmorgen, NY) at the International Textile Center (ITC), Texas Tech University, Lubbock, TX. This result was considered to be unsatisfactory. After optimizing the program according to indications from four tests (Qi et al., 1994c), 33 wool samples spanning the color range of the original 60 wools were remeasured. As a result, in CIE's XYZ Color Space, the r values between X, between Y and between Z of measurements made with the TAES System versus a colorimeter were 0.950 (P < 0.0001), 0.940 (P < 0.0001) and 0.926 (P < 0.0001), respectively.

The program for quantifying colored fiber content in white fleeces distinguishes among white, pigmented fibers (dark brown and black) and stained/yellow fibers. The only existing U.S. method (ASTM, 1993c) requires manual counting of colored fibers in a specific weight of wool top. Results are reported as numbers of colored fibers per unit weight (15g) of wool top. The image analysis program is designed to count both pigmented and stained/yellow fibers, and report results as percentages of total fibers observed. Therefore, a direct comparison between image analysis results and results of ASTM standard method was not attempted.

Information concerning proportions of pigmented and stained/yellow fibers can be used in guiding animal breeding and management decisions as well as in quality control in the wool and mohair textile industries. Preliminary comparison of the results obtained using the image analysis program with manual measurements made on a projection microscope indicates the image analysis program has reasonable accuracy. Advantages of this automatic image analysis program include its high speed of

Table 1. Proposed applications of the TAES Automatic Image Analysis System.

Proposed application	Progress to date
Average fiber diameter and its distribution	Finished
Wool staple length and its distribution	Finished
Mechanical yield of cashmere	Finished
Colored fiber content (pigmented and stained fibers)	Finished
Medullation in mohair (med and kemp percentages)	Continuing[a]
Color of scoured fibers	Finished
Luster in mohair, wool and cashmere	Started
Crimp in wool and cashmere	Pending
Style and character in mohair	Pending

[a] Further improvement of the program is needed to increase accuracy and precision.

Table 2. Evaluation of the average fiber diameter program using Interwoollabs IH tops.[a]

Top identity	Average fiber diameter	
	Stated values (Y, μm)	Measured values (X, pixel)
1	23.70	7.86
2	37.73	11.56
3	22.73	7.47
4	17.65	6.37
5	25.62	8.19
6	20.32	6.85
7	29.16	8.84
8	17.16	6.36

[a] Regression equation: Y = –7.0043 + 3.9387 X (r = 0.994, P < 0.0001).

measurement and the ability to distinguish between pigmented and stained/yellow fibers.

Beyond the described applications, this system has potential for measuring: 1) crimp in wool and cashmere; 2) style and character in mohair; and 3) luster in wool, mohair, cashmere and synthetic fibers. Programs for measuring crimp, style and character, and luster of animal fibers are in preparation.

Preliminary evaluation of the new programs for fiber characterization using the TAES Automatic Image Analysis System indicates that this system can be used for multiple types of measurement. The major advantage of the System is its versatility. Commercial users would need only to invest in one system which could perform multiple tasks. Availability of such measurements would have the potential of reducing costs of fiber testing and thus permit U.S. producers to better afford more fiber tests which in turn could result in enhanced selection for and marketing of wool, mohair and cashmere. Commercialization of this system is under investigation.

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Table 3. Standardization of staple length measurement and comparison of staple lengths by the image analysis program versus ruler measurement

Number	Staple length: Actual[a] (Y, cm)	Staple length: Program-measured (X, pixels)
1	5.00	122.48
2	8.00	162.82
3	10.00	184.26
4	12.00	220.32
5	15.00	258.65

Staple number	Program length, pixels	Predicted length, cm	Actual length, cm[a]	Residual error, cm[b]
1	241.47	13.76	14.00	0.24
2	135.71	6.08	6.00	-0.08
3	220.03	12.20	12.00	-0.20
4	175.41	8.96	9.00	0.04

[a] Staples were manually cut into these lengths and were then used as "absolute" standards. Standardization of the measurement by the image analysis program to actual length: $Y = -3.7724 + 0.0726\,X$ ($r = 0.998$, $P < 0.01$).

[b] Residual error calculated as actual length minus predicted length.

Table 4. Evaluation of the image analysis program for measuring medullation in mohair.

Sample identity	Standard method[a]			Image analysis program[b]		
	Med, %	Kemp, %	Total, %	Med, %	Kemp, %	Total, %
1	4.23	1.37	5.60	4.27	1.56	5.83
2	1.27	1.96	3.23	1.58	0.61	2.19
3	1.83	2.93	4.76	6.09	2.47	8.56
4	1.75	0.23	1.98	2.26	0.72	2.97
5	1.31	2.42	3.73	3.38	1.32	4.70
6	2.70	0.86	3.56	2.98	1.18	4.16
7	2.09	3.19	5.28	1.33	0.41	1.74
8	3.25	0.74	3.99	2.82	0.89	3.71
9	2.83	2.16	4.99	5.21	2.01	7.22
10	0.61	0.44	1.05	2.93	0.73	3.66

[a] Average of more than 10,000 fibers measured by five technicians.

[b] Average of 5,000 fibers measured.

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Effects of Lifetime Selection for Kilograms of Lamb Weaned per Ewe on Ewe Milk Production, Ewe and Lamb Feed Intake and Body Weight Change[1]

W.A. Head, Jr.[2], P.G. Hatfield[3], J.A. Fitzgerald[3],
D.M. Hallford[2], M.K. Petersen[2] and J.N. Stellflug[3]

Summary

Targhee ewes (n = 44; average age = 5 years) rearing twin lambs were used to investigate differences in body weight (BW), dry matter intake (DMI) and milk production associated with selection pressure for lifetime production of kilograms of lamb weaned per ewe. Measurements taken were milk production, ewe and lamb BW, lamb beta-hydroxybutyrate concentration (ß-HBA), ewe and lamb fecal output as a percent of BW, ewe and lamb digestion coefficients and ewe and lamb forage intake as a percent of BW. Period 1 started on day 4 postpartum and was conducted in confinement. Periods 2, 3 and 4 were conducted on fenced inter-mountain sagebrush-bunchgrass range starting at an average of 49, 84 and 112 days postpartum, respectively. Data were analyzed across periods and included effects for selection. Ewe and lamb age, lamb sex and birth weight were tested when applicable. Ewes selected for lifetime production of kilograms of lamb weaned per ewe (selected) produced more milk ($P = 0.10$) than random-bred control (control) ewes. Lambs raised by selected ewes were heavier ($P = 0.01$) than control lambs. Ewe BW tended to be higher ($P = 0.17$) for selected compared to control ewes during the entire study. Selected ewes were heavier at the initiation of the study and lost more ($P = 0.01$) BW than control ewes. Ewe fecal output expressed as a percent of BW, digestion coefficient and DMI (% BW) did not differ ($P \geq 0.53$) between selected and control ewes. Lamb fecal output ($P = 0.06$), DMI ($P = 0.17$) and ß-HBA ($P = 0.06$) were greater for selected than control lambs. Twin lambs from ewes selected for increased kilograms of lamb weaned were heavier than the random-bred control lambs (in part) because of higher energy intake, in the form of both milk and grazed forage.

Key words: sheep, selection, weaning weight, forage intake.

Introduction

Differences in growth rate of different genotypes can arise only from differences in nutrient intake, efficiency of nutrient utilization, partitioning nutrients into different body tissues or some combination of these possibilities (Frisch and Vercoe, 1991). However, few selection studies have investigated the effects of selection pressure on nutrient intake and utilization by the ewe and lamb.

Ercanbrack and Knight (1994) reported a marked difference for kilograms of lamb weaned per ewe between Targhee sheep selected for lifetime production of kilograms of lamb weaned per ewe (selected) and random-bred control ewes (control) over a 12-year period (34.2 and 28.0 kg for selected and control ewes, respectively). Stellflug et al. (1994) demonstrated that part of this difference could be attributed to higher reproductive performance. The selected line had higher ovulation rates than the control line. A similar selection study was conducted in California using Targhee sheep in both adequate and marginal nutritional environments (Lasslo et al., 1985). These researchers also found a positive response to weight selection.

Neither of these selection studies have investigated the energetic costs associated with the selection criteria based

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[2] New Mexico State University, Las Cruces, NM 88003-0003.

[3] USDA-ARS, U.S. Sheep Experiment Station, Dubois, ID 83423.

on kilograms of lamb weaned per ewe. Our study was designed to investigate differences in BW, ewe milk production and ewe and lamb DMI between selected and control ewes and their twin lambs.

Materials and Methods

Forty-four Targhee ewes (average age = 5.0 ± 2.2 years; average BW = 78.0 ± 4.3 kg) which gave birth to twin lambs were used in the study. Treatments were: 1) a line of ewes selected for lifetime production of kilograms of lamb weaned per ewe (selected; n = 22); and 2) a random-bred control line of ewes (control; n = 22). All ewes were shed lambed. Male lambs were castrated two days postpartum. Eighty-eight lambs started the study and all 88 lambs remained at the end of the study.

Data were collected in four periods. Period 1 (P1; 4 through 25 days postpartum) was conducted with each ewe and her twin lambs confined separately in 25 m^2 pens and allowed ad libitum access to chopped alfalfa hay (Table 1). Periods 2 (P2; 26 through 49 days postpartum), 3 (P3; 50 through 84 days postpartum) and 4 (P4; 85 through 120 days postpartum) were conducted on fenced inter-mountain sagebrush-bunchgrass range (Table 1) at the U.S. Sheep Experiment Station near Dubois, ID. Ewe and lamb BW were recorded at the beginning and end of each period.

Ewe milk production was estimated by hand-milking. Twenty USP units of oxytocin (intravenous) was used to stimulate milk letdown. Lambs were separated from the ewes at 0730 hours on the days that milk production was estimated. Ewes received an intravenous injection of oxytocin and were hand-milked until dry. Three hours later this process was repeated and milk was collected and volume measured. Milk production was estimated on 4, 11, 18 and 25 days postpartum for each ewe during P1 and at approximately 49, 84 and 112 days postpartum for each ewe during P2, P3 and P4, respectively.

Blood was sampled from the younger half of the lambs on the same day that ewe milk production was estimated. Blood samples were collected from the younger half of lambs to minimize the variation in lamb age. Blood was collected by jugular venipuncture at hourly intervals for six hours (0730 to 1230). Serum beta-hydroxybutyrate (ß-HBA) was determined by a colormeteric enzymatic kit (Sigma Diagnostics, P.O. Box 14508, St. Louis, MO 63178) using a spectrophotometer set at a wavelength of 340 nm.

Ewe fecal output was estimated using continuous release chromic oxide boli in all periods (Captec Chrome; Nufarm Ltd., Manu St., Othunu, Box 220-407, Auckland 6, NZ). In P2, lamb fecal output was determined by daily dosing with gelatin capsules containing 0.5 g chromic oxide (Cr_2O_3). In P3 and P4, lambs received a continuous release chromic oxide bolus. Boli and encapsulated Cr_2O_3 were allowed six days to equilibrate, then daily rectal grab samples were collected for seven consecutive day at 1000 hours each day. Fecal samples were grouped by animal within period and ground through a 1-mm screen in a Cyclone mill. Fecal samples were prepared for chromium analysis (atomic absorption) by digesting a 0.5 g ashed fecal sample in a phosphoric acid/ manganese sulfate solution and a potassium bromate solution (Williams et al., 1962).

In P1, ewe fecal output was estimated to determine digestion coefficients. Digestion coefficients for ewes and lambs were estimated using acid insoluble ash (AIA) during periods 2, 3 and 4 (Block et al., 1981). Ruminally-fistulated ewes that grazed the same study sites were used to collect ingesta samples. Rumens of fistulated ewes were evacuated, ewes were allowed to graze for 30 minutes, then ingesta samples were collected and original rumen contents replaced. Ingesta samples were washed and then frozen for later analyses. Acid insoluble ash was determined by procedures described by Goering and Van Soest (1970). Diet digestibility was calculated by dividing feed AIA by fecal AIA. Forage intake was calculated by dividing fecal output by diet indigestibility.

Data were analyzed across periods using the GLM repeated measures procedure of SAS (1985). The ewe model for milk production, BW, digestion coefficients, fecal output and DMI (% BW) included effects for selection with ewe age and lambing date tested as covariables. Lamb model for BW, digestion coefficients fecal output, DMI (% BW) and serum ß-HBA included effects for selection and sex with lamb age tested as covariables. Lamb birth weight and ewe BW were also tested as covariables where appropriate.

Table 1. Percent organic matter (OM) and crude protein (CP) of feed and forage in each period.[a]

Period	OM %	CP %
P1	91.6	16.5
P2	92.2	6.6
P3	89.2	6.4
P4	87.8	7.0

[a] Period 1 was conducted in drylot with ewes and lambs fed a diet of chopped alfalfa hay from April 28 to June 3, 1993. Periods 2, 3 and 4 were conducted on intermountain sagebrush-bunchgrass range from June 3 to September 8, 1993.

Results and Discussion

Lambs from selected ewes were 5.6% heavier at birth (P = 0.03) than lambs from random bred control ewes. When lamb BW from 4 to 120 days postpartum was evaluated using birth weight as a covariable, lambs from selected ewes maintained the heavier weight (P = 0.01) until weaning (Figure 1). At weaning, lambs from selected ewes were 6.8% heavier than lambs from control ewes. Selected ewes tended to be heavier (P = 0.17) during the entire study than control ewes (Figure 1). Selected ewes were heavier (P = 0.02) at the initiation of the study (81.4 and 74.8 kg for selected and control ewes, respectively) and lost 40% more BW (P = 0.01) from 4 to 120 days postpartum than control ewes (-10.5 and -6.3 kg for selected and control ewes, respectively).

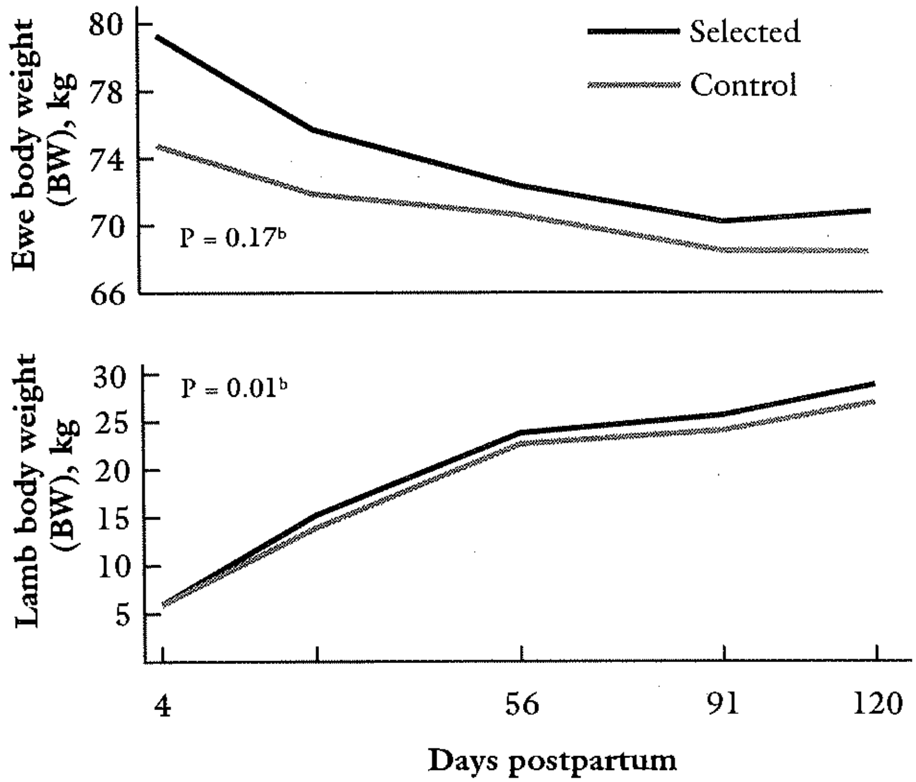
Selected ewes produced 13% more milk (P = 0.10; Figure 2) than control ewes. Brown et al. (1987) also found that Targhee ewes selected for increased lamb weaning weight had greater milk production. However, Geenty et al. (1985) stated that higher milk production alone can not explain all the variation in lamb weaning weights. These researchers found that despite large differences among breeds of sheep in milk production, differences in lamb growth were small.

Ewe fecal output and DMI expressed as a percent of BW and ewe digestion coefficient did not differ (P ≥ 0.53) between selected and random-bred control lines during the course of the study (Figure 3). However, selected ewes tended to have greater DMI (P = 0.14) during the period following peak lactation.

Montano-Bermudez et al. (1990) found that high milk-producing cattle have higher maintenance energy requirements than low milk-producing cattle. In addition, Wood et al. (1980) reported that higher milk-producing cattle lost more body weight and compensated by increasing nutrient intake during periods of low energy demand. The selected ewes lost more weight, produced more milk and potentially had a higher maintenance energy requirement, thus nutrient intake during periods of low energy demand may be higher for selected ewes than control ewes. Although we did not measure ewe DMI during periods of non-lactation or gestation, selected ewes appeared to be compensating as suggested by Wood et al. (1980) by their tendency to consume more feed after peak lactation than control ewes.

Lamb fecal output as a percent of BW was greater (P = 0.06) for lambs from selected ewes than for lambs from control ewes (Figure 4). Lamb DMI as a percent of BW tended (P = 0.17)

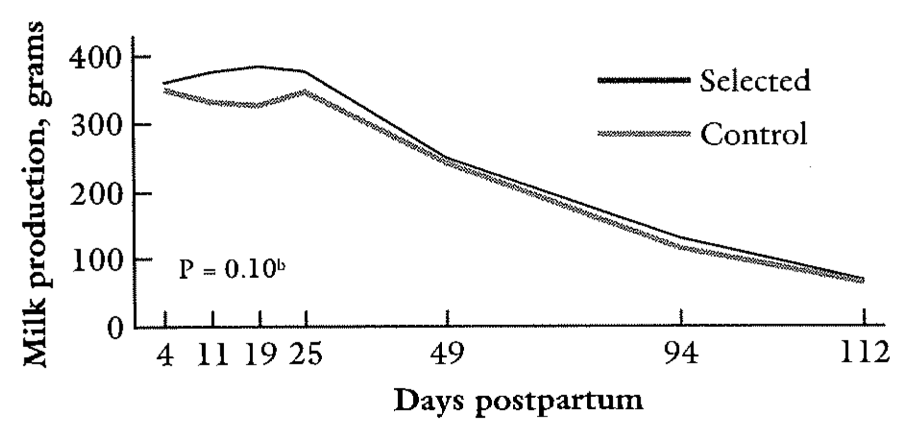
Figure 1. Ewe and lamb body weight (BW) in kilograms from 4 to 120 days postpartum for selected and control lines.[a]



[a] Standard errors for ewe BW were 1.94, 1.87, 1.77, 1.56, 1.67 and 1.13 kg for days 4, 25, 56, 91 and 120 postpartum, respectively. Standard errors for lamb BW were 0.16, 0.26, 0.56, 0.42 and 0.47 for days 4, 25, 56, 91 and 120 postpartum, respectively.

[b] P-value associate with repeated measures (over time) mean comparison.

Figure 2. Ewe milk production in grams from 4 to 112 days postpartum for selected and control ewes.



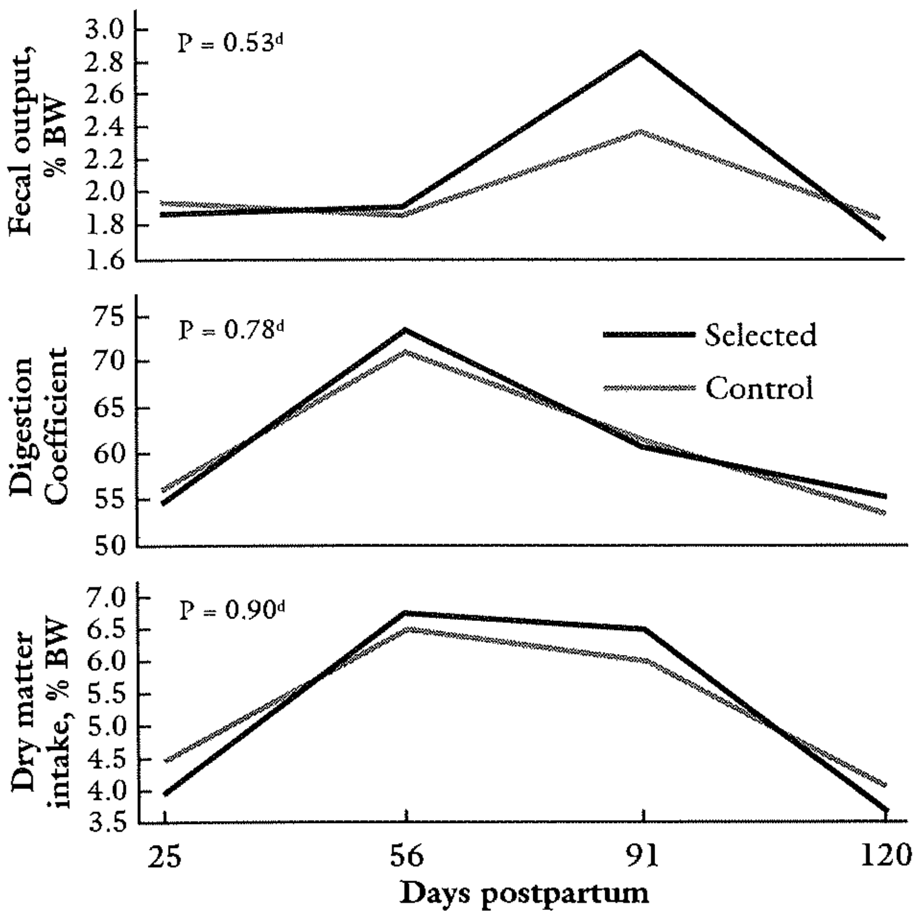
[a] Standard errors were ± 21.49, 15.81, 19.08, 24.05, 13.66, 7.82 and 4.36 grams for milk production on days 4, 11, 18, 25, 49, 84 and 112 postpartum, respectively.

[b] P-value associate with repeated measures (over time) mean comparison.

to be higher for selected lambs (Figure 4). Although digestion coefficient did not differ (P = 0.21) over the course of the study, digestion at 120 days postpartum was 3% higher (P = 0.11) for control than for selected lambs.

Blood volatile fatty acid concentrations generally increase with age and dry feed intake in ruminants (McCarthy et al., 1956). Most of the ruminal butyrate is metabolized to ketone in mature ruminants (Bergman 1975). In a study with lambs fed milk only or milk plus pasture, Walker and Simmonds (1962) reported increased ketogenic activity when dry feed was consumed. Therefore, in addition to estimating fecal output in lambs, we measured serum ß-HBA (a ketone) as an indicator of forage intake. These samples were collected primarily to make inference to forage intake by lambs at an early age before it was practical to use an external marker to estimate fecal output. Lamb serum ß-HBA was higher (P = 0.06) for selected than for control lambs (Figure 5). The higher concentration of ß-HBA in selected lambs indicates that selected lambs consumed more fiber than control lambs. Thompson et al. (1985) also found that Australian Merino sheep selected for high weaning weight had a higher intake at an earlier metabolic age than sheep selected for low weaning weight.

Figure 3. Ewe fecal output expressed as a percent of body weight (BW), ewe digestion coefficient and ewe dry matter intake (DMI) as a percent of BW from 25 to 120 days postpartum for selected and control ewes.[a,b,c]



[a] Standard errors for ewe fecal output as a percent of BW were ± 0.26, 0.18, 0.31 and 0.17% for 25, 56, 91 and 120 days postpartum, respectively.

[b] Standard errors for ewe digestion coefficients were ± 3.62, 1.13, 1.35 and 1.19% for 25, 49, 84 and 120 days postpartum, respectively.

[c] Standard errors for ewe DMI as a percent of BW were ± 0.15, 0.51, 0.55 and 0.49% for 25, 56, 91 and 120 days postpartum, respectively.

[d] P-value associate with repeated measures (over time) mean comparison.

Animal production is energy driven (Frisch and Vercoe, 1991). In our study, lambs from the selected line of ewes consumed more energy than lambs from the control line of ewes. Certainly efficiency of nutrient utilization at the cellular level could play a role in the difference in weaning weight between selected and control lambs. However, Thompson et al. (1985) stated that growth efficiency with which food was converted to body weight did not differ between Australian Merino sheep selected for high and low weaning weights. Our results indicate that selected lambs were heavier at weaning, in part because of a higher energy intake in the form of milk and forage consumption.

Conclusions

Twin lambs from ewes selected for kilograms of lamb weaned were heavier, consumed more milk, had greater ß-HBA and fecal output values and tended to consume more DM than twin lambs from the randombred control line of ewes. Regardless of whether intake drove growth or growth drove intake, more energy must be available for more growth. Our results clearly demonstrate that the cost for higher production of lamb weaned per ewe is higher levels of intake for the lamb and potentially higher maintenance energy requirements for the ewe.

Animal agriculture must focus on the optimum rather than the maximum. Input costs are paramount in determining the profitability and consequently the viability of the sheep industry. Therefore genetic improvement can only be made in light of nutrition costs associated with the change in output.

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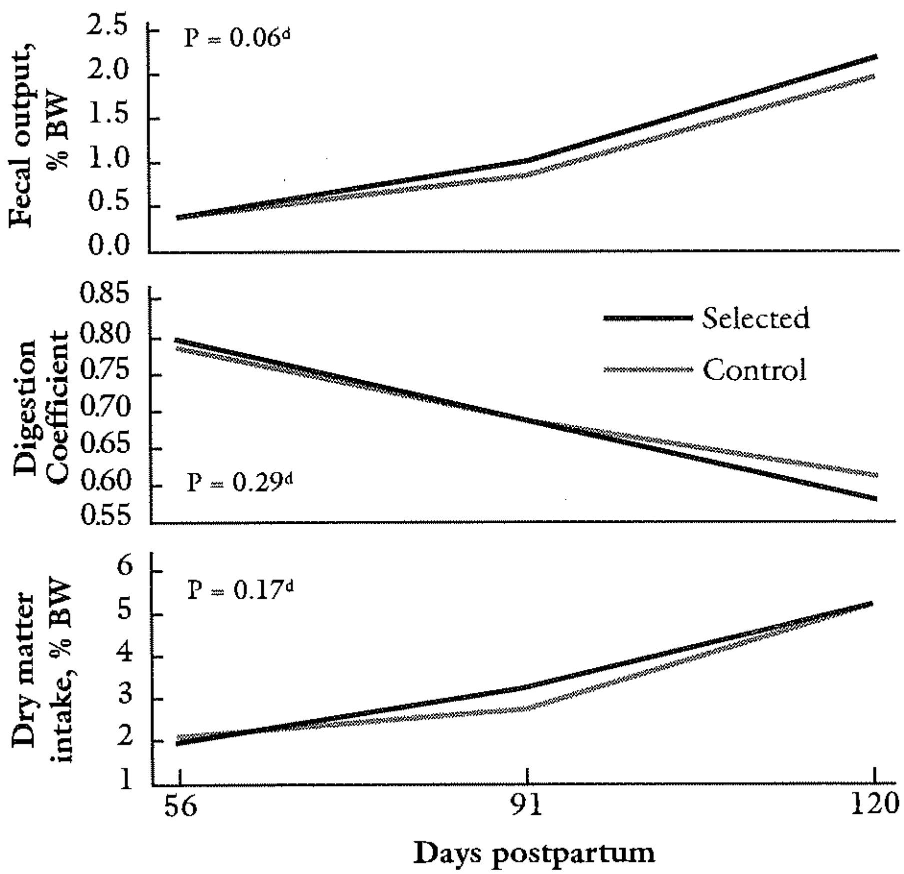
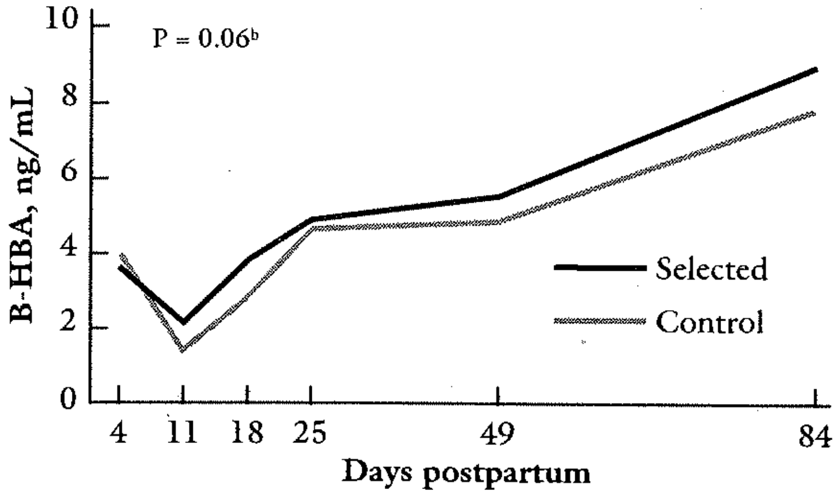
Figure 4. Lamb fecal output expressed as a percent of body weight (BW), digestion coefficients and dry matter intake (DMI) as a percent of BW for 56, 91 and 120 days postpartum for lambs.[a,b,c]



[a] Standard errors for lamb fecal output as a percent of BW were ± 0.02, 0.05 and 0.10% for 56, 91 and 120 day postpartum, respectively.
[b] Standard errors for lamb digestion coefficient were ± 0.005, 0.007 and 0.012% for 56, 91 and 120 day postpartum, respectively.
[c] Standard errors for lamb dry matter intake as a percent of BW were ± 0.12, 0.18 and 0.26% for 56, 91 and 120 day postpartum, respectively.
[d] P-value associate with repeated measures (over time) mean comparison.

Figure 5. Lamb serum beta-hydroxybutyrate (ß-HBA) concentrations in nanograms per milliliter from 4 to 84 days postpartum.



[a] Standard errors for ß-HBA were 0.47 0.58, 0.35, 0.26, 0.25 and 0.46 nanograms per milliliter for 4, 11, 18, 25, 49 and 84 days postpartum, respectively.

[b] P-value associate with repeated measures (over time) mean comparison.

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Comparison of Efficacy of Two Commercially Available Ovine *Chlamydia psittaci* Abortion Vaccines[1,2]

Marie S. Bulgin[3], Gary Snowder[4], Alton C.S. Ward[3], Kim Hemenway[5], Mary Tinant[6] and Hudson Glimp[7]

Summary

The efficacies of two commercially available *Chlamydia psittaci* vaccines were compared with non-vaccinated controls in relationship to age of ewes, their antibody response against Chlamydia before and following vaccination and the incidence of abortion in a large range flock. Ewes were vaccinated with either a Grand Laboratories product (GL) or a Colorado Serum Company product (CS) seven weeks before, and a booster vaccination three weeks before, exposure to rams. Approximately 3% of the total 2,716 ewes lambing aborted. Abortion rates among pregnant ewes within treatment groups were not statistically different: 4% for non-vaccinated controls (CNTRL), 3% for GL and 3% for CS ewes. The incidence of positively diagnosed chlamydial abortion from tissue smears and complement fixation titers was 47% of the abortions. Complement fixation titers for Chlamydia in the vaccinated groups versus control animals showed no more than a one dilution rise in antibody titer even after the booster vaccination. Vaccine treatment did not improve the percent of ewes lambing (reduce early abortion) or the percent of lambs born live per ewe lambing (reduce stillbirths) when compared to the CNTRL population. There was no observed economic advantage to using the vaccines based on little or no reduction in the incidence of chlamydial abortions.

Key words: abortion, chlamydia, enzootic, sheep.

Introduction

Chlamydial abortion, also known as enzootic abortion of ewes (EAE), is the most common cause of abortion in the western United States. Not only is it of economic importance to the sheep industry in the U.S., but it also causes abortion and critical illness in pregnant women (Linklater, 1991). The agent, *Chlamydia psittaci*, is an obligate intracellular parasite introduced into susceptible flocks by infected sheep which may shed the organism in feces as well as uterine discharges (Storz, 1971; Shewen, 1980). Because ewes become immune after exposure and infection, flocks chronically infected with the agent generally have a low annual incidence (0.7% to 4%) of abortion usually experienced in first or second gestational ewes (Storz, 1971). However, when the agent is first introduced into a susceptible flock, incidences of 15% to 33% affecting all ages have been reported (Storz, 1971).

Development of placental and subsequent fetal lesions do not commence until after 90 days gestation regardless of when the ewe becomes infected, and abortions are usually seen between 120 and 150 days (Linklater, 1991). Mummies, stillbirths, weak lambs, undersized lambs and poor-doing lambs are also commonly experienced in flocks affected with *C. psittaci*. Furthermore, female fetuses may be infected late in gestation, survive, carry the organism and subsequently abort their first lamb(s) (Wilsmore et al., 1984).

Vaccines have been used for control of Chlamydial abortion with varied

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[2] The use of a commercial product or its brand name implies no approval or endorsement of the product by state and federal research institutions.

[3] University of Idaho, College of Agriculture, Department of Animal and Veterinary Science, Caldwell, ID 83605

[4] USDA-ARS, U.S. Sheep Experiment Station, Dubois, ID 83423.

[5] College of Agriculture, University of Idaho, Dubois, ID 83423.

[6] Grand Laboratories, Inc., Larchwood, IA 51241.

[7] Veterinary Medicine Department, University of Nevada, Reno, NV 89557-0004.

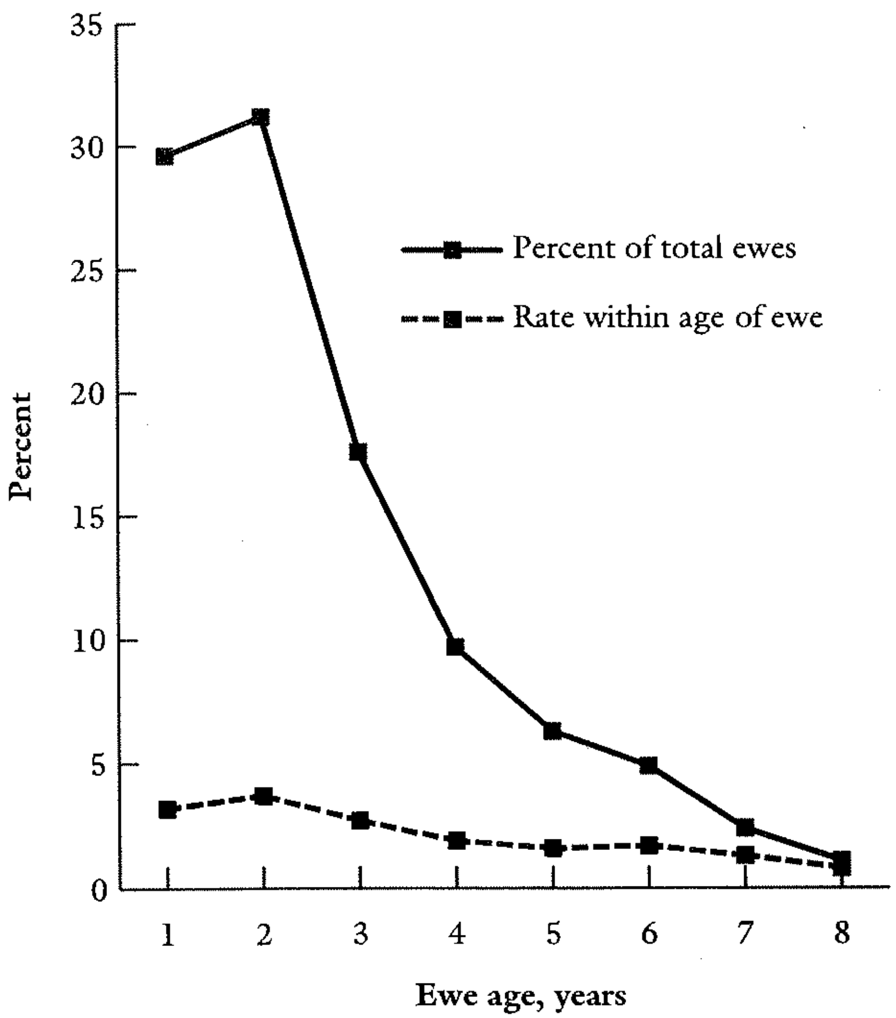
success (Hulet et al., 1965; Waldhalm et al., 1971; Meinershagen et al., 1971). In the United Kingdom, a crude formalinized preparation of *C. psittaci* cultured in embryonated eggs and combined with an oil adjuvant has been used for 30 years (Linklater, 1991). Presently, there are two commercially available vaccines in the U.S. They contain one or two isolates of *C. psittaci* grown in cell culture. Both vaccines contain *Campylobacter fetus ss fetus* and *C. jejuni;* and one of these vaccines also contains four strains of K99 positive *Escherichia coli.* The efficacy of these vaccines has been questioned due to Chlamydia-caused abortion occurring in flocks vaccinated according to the manufacturers' recommendations.

This report compares the efficacies of two commercially available *C. psittaci* vaccines: 1) *Campylobacter fetus-Chlamydia psittaci-Escherichia coli* bacterin (Grand Laboratory, RR3, Freeman, SD 57029) and 2) *Campylobacter fetus-Chlamydia psittaci* bacterin (Enzabort; Colorado Serum Co., Denver, CO 80216) with non-vaccinated controls in relationship to age of ewes, their antibody response against Chlamydia before and following vaccination and the incidence of abortion in a large range flock.

Materials and Methods

A flock of approximately 3,000 range ewes of six different breeds (Columbia, Polypay, Rambouillet, Suffolk, Targhee, and 1/4 Finn crosses) at the USDA-ARS, U.S. Sheep Experiment Station (USSES) in Dubois, ID, has a long-diagnosed history (since 1958) of Chlamydial abortions (Hulet et al., 1965). This was basically a closed flock; only a limited number of Suffolk rams from outside flocks had been brought in to prevent inbreeding in a small Suffolk population (approximately 75 ewes). The average annual abortion rate in the flock from 1985 to 1992 was 2.6% with a low of 1.5% in 1992 and a high of 4.2% in 1987. Abortion rates were negatively associated with age of ewe; higher abortion rates were observed in younger ewes (Figure 1).

Figure 1. Average abortion rates within ewe age groups from 1985 to 1992.



Ewes (17 months to 7 years of age) identified by eartag number were randomly assigned by computer into three treatment groups without regard for breed or age. The number of CNTRL animals was limited to 194 head to prevent potential abortions from reaching an unacceptable economic level. The two remaining groups received either the Grand Laboratories product (GL) or the Colorado Serum Co. product (CS) seven weeks before, and a booster vaccination three weeks before, exposure to rams. The immunization procedure followed label instructions for each vaccine. The GL vaccine (5 ml) was given intramuscularly into a hind leg of each ewe; the CS vaccine (2 ml) was given subcutaneously in the neck region. After vaccination, there was no attempt to keep treatment groups separated.

Ewes were placed by breed in single sire pens for 22 days for breeding, then exposed to Suffolk rams for 25 days in two large flocks. After breeding, ewes grazed a winter desert range in eastern Idaho for approximately 65 days under herder supervision from mid-December to mid-February. Ewes in large groups were then fed alfalfa pellets and whole barley while in confinement for 30 days prior to the onset of lambing. Lambing occurred in March and April.

Blood was collected for complement fixation (CF) testing from 56 head of ewe lambs (22 vaccinated with GL; 23 vaccinated with CS; 11 CNTRL) and 64 mature ewes of varying ages (24 vaccinated with GL; 27 vaccinated with CS; 13 CNTRL). Complement fixation (CF) testing was performed at the Texas Veterinary Medical Diagnostic Laboratory (College Station, TX 77841-3040). Pre-vaccination serum samples were collected via jugular puncture immediately prior to initial vaccination. Post-vaccination samples were taken just prior to the booster injection and four weeks later.

Blood was also taken from 38 ewes immediately after abortion occurred and four weeks later. Ten other ewes having normal lambs were sampled at parturition and four weeks later in the same manner. All blood serum samples were tested by CF for titers to *C. psittaci*. Aborted fetuses and placentas were frozen, packed into styrofoam mailing containers and sent to the University of Idaho's Caine Veterinary Teaching Center (Caldwell, ID 83605). The boxes were unpacked upon arrival at the laboratory and specimens allowed to thaw. Placentas were examined for cotyledons with necrotic areas and such typical lesions were used for making impression smears. Several normal-appearing cotyledons were chosen randomly if no abnormalities were observed. Impression smears were stained using the Gimenez and Gram's stain, respectively; and smears were carefully examined under oil immersion for evidence of intracellular elementary bodies or other pathogenic organisms such as Brucella, Campylobacter, Toxoplasma, Salmonella or Coxiella. A fluorescent antibody technique utilizing a monoclonal antibody was employed for confirmation of questionable Chlamydia diagnoses.

Fetuses were necropsied and samples were taken of liver, lung and stomach contents with sterile scissors and forceps. These samples were homogenized by the use of a stomacher and aliqouts plated on Columbia agar with added 5% ovine blood (CBA), a Campylobacter selective medium with 10% ovine blood, Bacitracin (15 units/ml), Polymyxin B (1 unit/ml), Cycloheximide (20 µg/ml) and Novobiocin (5 µg/ml) in brain-heart infusion agar and inoculated into Thioglycollate media. The CBA plates were incubated in an atmosphere of 10% CO_2 at 37 °C and examined daily for 5 days and again at 14 days when final examination was made. The selective media was incubated in Campy gas pacs at 37 °C and examined daily for five days. Bacterial growth, if present, was examined and identified by standard bacterial methods with special effort being given for Campylobacter, Brucella ovis, Listeria, Actinobacillus, Histophilus ovis and Salmonella (Carter and Cole, 1990).

Statistical analyses of the flock's reproductive data included an analysis of variance using the CATMOD procedure of SAS (SAS, 1989). The effect of vaccine, breed, age group and their interactions were tested on fertility and number of lambs born. Differences in abortions rates as a percentage were tested by the Chi-square test in the FREQ procedure of SAS for the effects of vaccine, breed, age group and their interactions. Differences of titers from CF testing for *C. psittaci* were determined by the Chi-square test for the treatment means of the titer natural log.

Results and Discussion

Of the 83 ewes which aborted, placental and fetal tissue samples from 75 abortions were submitted to the laboratory for diagnosis. Of the 75 submissions for examination, 30 (40%) were positive for Chlamydia on smears. The CF test for Chlamydia demonstrated high antibody titers (more than 16) in five additional ewes, indicative of recent Chlamydia infection, making a total of 35 definitive diagnoses. This increased the incidence of positively-diagnosed chlamydial abortion to 47%. No other infectious agents were detected in any of the samples. Abortion rates among pregnant ewes within groups were 4.0% for CNTRL, 2.9% for GL and 3.0% for CS ewes (Table 1). Abortions rates were not statistically different among treatment groups. Positively diagnosed chlamydial abortions were lowest in the CNTRL group (29%) and significantly higher in the GL (40%) and CS (51%) vaccinated groups.

Of the 38 aborting ewes which had serum tested by CF for Chlamydia, Chlamydia was detected in placental smears of only 12 ewes. These 12

Table 1. Incidence of abortions and positively diagnosed chlamydial abortions in vaccinated and non-vaccinated ewes.

Treatment	Total no. of pregnancies	Percent abortions	Chlamydial abortions, %[a]
Control	174	4.0	29[b]
GL	1,261	2.9	40[c]
CS	1,281	3.0	51[c]

[a] Percent chlamydial abortions based on direct examination of placental impression smears and CF tests on samples from 75 abortions.
[b,c] Percent abortions with different superscripts differ ($P < 0.05$).

Table 2. Mean complement fixation titers for Chlamydia prior to and post first and second vaccination by ewe age and treatment.

Group	Treatment	No.	Pre-vaccination	Post first vaccination	Post second vaccination
Ewe lambs	Control	23	16	8	4
	GL	22	16	<2	<2
	CS	11	16	16	4
Mature ewes	Control	27	32	32	64
	GL	24	<2	<2	<2
	CS	13	16	16	32

ewes had acute titers which ranged from 4 to 64. Except in one case in which the titer changed from 4 to 16, convalescent titers were the same as acute or had only a one dilution (twofold) change.

Complement fixation titers in the vaccinated (regardless of which group) versus control animals in this study showed no more than a one dilution rise in antibody titer even after the second vaccination. In the case of the ewe lambs, the titer actually fell (Table 2).

The logarithmic transformed CF titers for ewes with aborted and normal pregnancies are reported in Table 3. The 10 ewes with normal lambing had CF titers which ranged from less than 2 (5 ewes) to 32 (2 ewes) and logarithmic titers were significantly lower than those of aborted ewes. In all cases of diagnosed chlamydial abortions, the convalescent titers stayed the same or changed only by 1 dilution from the acute titers. Chlamydial abortions were not definitely diagnosed in 48 of the 83 aborting ewes which tested negative for placental smears and whose CF titers ranged from less than 2 to 64. Of these 48 aborting ewes, 31 had convalescent samples taken and only one, a CS ewe, had more than a twofold rise in titer (from 8 to 32) and may be considered to have aborted due to chlamydial infection.

Although the breeds used in this study are significantly different in fertility and prolificacy, there was no difference in abortion rates between breeds. As expected, fertility rates as measured by percent of ewes lambing were different between age groups; younger ewes displaying lower fertility. Fertility and percent of live lambs within age groups were not increased by vaccine treatment (Table 4). Vaccine treatments did not improve the percent of ewes lambing (reduce early undetected abortion) or the percent of lambs born live (reduce stillbirths) per ewe lambing when compared to the CNTRL population.

Table 3. Average acute and convalescent logarithmic complement fixation titers for Chlamydia in vaccinated and non-vaccinated ewes with normal or aborted pregnancies.

Treatment	Pregnancy outcome	Microscopic[a] examination	Acute[b]		Convalescent[c]	
			No.	Titer	No.	Titer
Control	aborted	negative	1	2.08	1	2.58
	aborted	positive	2	1.39	2	1.39
GL	aborted	negative	15	1.99[d]	10	1.80[d]
	aborted	positive	6	3.35[d]	6	3.23[d]
	normal	50.00e	5	0.55[e]	–	–
CS	aborted	negative	10	1.80[d]	3	3.23[d]
	aborted	positive	14	3.91[d]	14	3.91[d]
	normal	–	5	0.55[e]	5	0.27[e]

[a] Microscopic examination for Chlamydia in placental smears.
[b] Blood sampled on day of abortion.
[c] Blood samples 28 days after abortion.
[d,e]Titers with different superscripts within treatment differ ($P < 0.05$).

Table 4. Fertility and percent of live lambs born to ewes vaccinated for chlamydial abortion and non-vaccinated ewes by age group and vaccine.

Age group[a]	Total no.	Ewes lambing, %			Lambs born live per ewe lambing, %		
		Control	GL	CS	Control	GL	CS
1	764	87	88	87	95	95	93
2	753	100[b]	94[c]	94[c]	95	94	94
3	1,486	93	94	93	91	93	93
Total	3,003	90	91	90	94	94	93

[a] Age group: 1 = 17 months to 2 years; 2 = 3 years; 3 = 4 to 7 years.
[b,c]Means with different superscripts differ within age groups and vaccine treatment ($P < 0.05$).

Food and mixed-animal practitioners are consulted by sheep producers for recommendations concerning abortion prevention. Because most practitioners have only a small sheep-producing clientele, their experience with the results of preventative abortion methods are limited. If available, veterinarians generally recommend the use of vaccines. For this reason, such studies as this are of particular interest.

For a vaccine to be of practical significance, it must be economically advantageous. Vaccine costs vary depending upon the manufacturer and vaccine components. In this case, the cost of vaccinating a flock of 3,000, (510 young replacements ewes with two injections and 2,490 adult ewes with only one injection) at a vaccine cost of $1.00 per dose and labor cost of $410.00 would equal $3,930.00. If this flock averaged an annual abortion rate without vaccination of 5% (loss of 135 lambs per year), had a lambing percentage of 150% and sold 100-pound lambs at $0.60 per pound, the product must reduce the loss from 135 to less than 69 lambs per year or to an abortion rate of less than 1.5%. This study found that the incidence of chlamydial abortions decreased from 4% in the controls to 2.9% or 3% in the vaccinated group. This reduction was not statistically significant.

Only 40% of the submissions were diagnosed as Chlamydia. However, no evidence of other known infectious abortive agents was detected. Furthermore, the low number of diagnoses is not particularly unusual when dealing with Chlamydia. Chlamydia is a difficult organism to grow in the laboratory. However, culture of specimens either in embryonated eggs or tissue culture may have improved the diagnostic effort. In our laboratory, positive diagnoses of Chlamydia in field samples were increased by 22% when tissue culture was used, but this technique is not implemented routinely due to cost and labor. In a British study, though, only 14 of 78 (18%) and 36 of 95 (38%) fetal membranes, in two respective years, infected with *C. psittaci* were identified as such by stained smears (Dagnall and Wilsmore, 1990). The other contagious abortion agents of sheep (Campylobacter, Salmonella, Brucella ovis) are relatively easy to culture. Therefore, based on the number of positive diagnoses, character, time of the abortions, incidence, documented flock history and the absence of finding other pathogenic organisms, Chlamydia was felt to be responsible for most of the abortions experienced by the flock.

Serology has not been shown to be particularly useful for routine diagnosis of Chlamydia abortion. As shown in this study, infection does not usually cause an increase in antibody titer after an abortion. In chlamydial infections, antibody concentrations exhibit two peaks, the first one is seen within 30 days of initial infection; the average time to see a significant titer after exposure in naturally infected ewes is 12 days (Blewett et al., 1982), and the second at time of abortion after which it gradually declines (Rodolakis and Souriau, 1980). Higher titers, however, when seen, are evidence of exposure.

The serological results of our study were similar to another recent survey of ewes in North Missouri which were injected with one or the other of the same two vaccines (Keisler et al., 1989). Ewes in that study showed no antibody response after vaccination compared to the control animals. Chlamydial abortion did not appear to be a problem in this flock and no comparison of efficacy could be made between vaccinated and unvaccinated ewes. However, an efficacy study against the natural disease was done in Oregon using the Chlamydia-Campylobacter-*E. coli* combination vaccine before it became commercially available (Hansen et al., 1990). The authors claimed 80% effectiveness for the vaccine against natural Chlamydia-caused abortion as compared to unvaccinated controls. Unfortunately, there were no serological studies done in that trial for comparison to this study. Serology may have suggested a difference in antigenic density of the vaccine.

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Research Briefs

The Effect of Stage of Breeding Season or Pre-Mating Estrogen or Progesterone Therapy on Fertility of Ewe Lambs

Beck, N.F.G. and M.C.G. Davies

Department of Agricultural Sciences,
University of Wales, Aberystwyth
SY23 3DD.

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A major change in the sheep industry in recent years has been the widespread practice of breeding ewe lambs. It is well established that the breeding performance of ewe lambs is below that of mature ewes. It has been shown that much of this is due to embryonic mortality. These types of losses are indicated by prolonged inter-estrous intervals which is believed to be due to or indicative of luteal persistence caused by embryonic mortality after the 12th day of pregnancy. The losses of this nature are thought to be greater for ewe lambs bred at the first estrus (puberty). The authors conducted two studies with ewe lambs. In one of these, the ewes were bred at the first versus the third estrus, and in following studies attempts were made to simulate subsequent changes in endocrine status at the first, second and third estrous. Among the ewes mated at first versus third estrus, a highly significant difference in lambing results were noted, with 80.9% of ewes lambing to matings made at third estrus compared to 28.0% mated at first estrus. A substantial portion of this was due to ewes returning to estrus. In this study, mating at the third estrus represented a time lapse and an advance of the season. The authors conclude that "it is unlikely that the above factors were responsible for the difference in fertility between groups." The transition from first to subsequent estrus might be accomplished by running sterile rams with the ewe lambs and waiting until significant estrous activity is observed before placing with fertile males. Numerous studies in the U.S. with mature ewes have shown that it is possible to change lambing dates, but not lambing results, by use of sterile males with mature ewes prior to the breeding season. Based on this study, the results might be different with ewe lambs. In this study, the scientists attempted to simulate first, second and third estrus by treating the ewe lambs with 0.25 mg estradiol benzoate, followed in 48 hours with a progestogen pessary for 12 days. This treatment was repeated 1, 2 or 3 times to simulate first, second and third estrus. The simulated third estrus showed a significant improvement in the number of viable embryos compared to the first estrus. No such benefit was evident in comparing the simulated second estrus versus the first estrus. The reason for this result is not clear. In any case, the cost and lack of availability of the drugs would appear to suggest this regime would hold little interest to U.S. producers.

– Prepared by Maurice Shelton.

Effects of Dietary Supplementation of Vitamin E on Storage and Caselife Properties of Lamb Retail Cuts

Wulf, D.W., J.B. Morgain, S.K. Sanders, J.D. Tatum, G.C. Smith and S. Williams

Department of Animal Sciences, Colorado State University, Ft. Collins, CO 80528.

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The visual appearance of fresh meat in the display counter is important in respect to consumer perception of quality. Discoloration (over time) is caused by oxidation, especially of the lipid fraction. It has been previously shown that elevated dietary vitamin E provided greater resistance to lipid oxidation in beef, pork and poultry. Since lamb is often a slow-moving product in the retail case, the problem of discoloration due to oxidation may present a greater problem than with other species. A study was conducted in which 30 wether lambs were assigned to one of three treatment groups of 10 lambs each. One group served as a control and the two additional groups received 500 and 1,000 IU of vitamin E per head per day in the form of dl-alpha tocopheryl acetate for a 56-day feeding period. Feedlot performance and carcass data were recorded along with Alpha-tocopherol levels of lean tissue. The 500 IU level appeared to be adequate to bring about an increase in Alpha-tocopherol level of the tissue without any effect on animal performance. On the other hand, the 1,000 IU level significantly reduced animal performance (daily gain) on feed. Two legs and two loins from each treatment group were randomly assigned to one of four storage periods of 7, 14, 21 and 28 days at 2 °C. Following the appropriate storage period, the legs and loins were fabricated into retail cuts and wrapped in oxygen-permeable polyvinyl chloride packaging. These retail cuts were displayed under simulated retail-display conditions. Color changes were evaluated by three trained personnel at 0, 1, 3, 5 and 7 days. In this study the feeding of vitamin E for 56 days prior to slaughter significantly increased case life by approximately four days, which could be advantageous in merchandising the product. There was no appreciable advantage to 1,000 IU as contrasted to 500 IU in respect to extending caselife. It remains to be determined if lower levels of vitamin E would provide similar results.

– Prepared by Maurice Shelton

News and Notes

Meeting

The 1995 annual meeting of the American Society of Animal Science will be held July 25-28 at the Orange County Convention/Civic Center in Orlando, FL.

Information sessions will be held dealing with sheep and goats. For information on the session dealing with sheep, contact Dr. Lowell Slyter, South Dakota State University, Brookings, SD 57007. For information on the session dealing with goats, contact Dr. S. Gelaye, Fort Valley State College, P.O. Box 5744, Fort Valley, GA 31030.

Photocopying? Be careful!

Science (Vol. 266) reports that a federal appeals court decision "should prompt companies and universities to review their policies toward photocopying." The decision was the result of a suit filed in 1985 by approximately 80 publishers and organizations against Texaco on the basis that the corporation and certain employees violated U.S. copyright law because they copied and distributed articles to company researchers. The suit boiled down to charges against one Texaco chemist who copied articles and filed them in his office. It was speculated that if the scientist had made immediate use of the copied material, the case might have turned out differently; as it was, the Texaco scientist was viewed as creating "his own personal library." The court ruled against Texaco in the matter, adding that Texaco should have paid for a license from the Copyright Clearance Center or simply bought more subscriptions to the journal.

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

In citing literature in the text, use both authors if there are only two. If there are more than two, use the first author and et al. Authors are asked to provide "interpretive summaries" for use by the sheep and goat industries in other media.

Proofing

Primary authors will receive galley proofs of articles. Corrected proofs should be returned by the deadline indicated. Failure to do so will result in delay of article publication.

Reprints

Fifty reprints of each article will be provided at no cost to the primary author. When galley proofs are sent, the author will be requested to complete a reprint order form requesting free and any additional reprints and provide the name of the institution, agency or individual responsible for the reprint charges.

Charge

The publication charge for the Sheep & Goat Research Journal is $60.00 per page and position announcements are $30.00 per quarter-page or less. Contributors will be billed following publication. All manuscripts and correspondence should be addressed to the Sheep & Goat Research Journal, 6911 South Yosemite Street, Englewood, CO 80112-1414, unless noted otherwise on materials received from the editorial staff.

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Editorial Review Board

American Sheep Industry Association

6911 South Yosemite Street
Englewood, CO 80112-1414
Phone (303) 771-3500
Fax (303) 771-8200

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Volume 11, Number 3: 1995

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are on the following page.**

American Sheep Industry Association

Contents of Volume 11, Number 1: 1995

Contents of Volume 11, Number 2: 1995

Economic Issues and Potentials in Lamb Marketing: Keys to the Future of the Sheep Industry

Wayne D. Purcell[1]

Summary

The sheep industry is in a state of decline. Revenues from wool and lamb have not been sufficient to keep producers in business. Inventory numbers that exceeded 50 million head in the 1940s declined to less than 9 million head on January 1, 1995.

A major problem is a long and sustained decline in demand for lamb. Slaughter lamb sales constitute much of the revenue flow for many sheep producers. Product offerings, especially fresh lamb offerings, have often diverged from the needs and preferences of the modern consumer. A smaller total or per capita offering will often move into consumption only at lower inflation-adjusted prices. Modern consumers looking for products low in fat and cholesterol, consistent in quality and convenient to prepare may not find a fresh lamb offering that meets such criteria. The perceived value is low, therefore lamb prices are also low. Adjusted for inflation, slaughter lamb prices declined over 60% from 1978 into the early 1990s. The problem appears to be accentuated by inefficiencies or lack of competition at the middleman level, inefficiencies that drive producer prices down in the short run and retail prices up in the long run.

Given current industry structure, no single private-sector participant has a strong incentive to make needed investments in market and product development. Producers and producer groups will have to be the catalysts. Investments in market and product development must be made, and better coordination of activities may generate enough cost savings to provide the needed financing.

Key words: lamb, markets, demand, product development, coordination.

Introduction

The sheep industry in the U.S. is an industry in decline. In the early 1940s, total sheep numbers exceeded 50 million. By 1950, the number was near 30 million and inventories hovered near that 30 million-head level until the early 1960s. In the 1960s, a long-term downtrend started. By January 1, 1995, the inventory was below 9 million head (Figure 1).

Many and varied reasons have been given for the decline. A survey by Gee et al. (1977) identified low selling prices for lambs, predator losses and labor shortages as reasons for the decline. Parker and Pope (1982) also identified predator losses and labor shortages, and they added the lack of adequate research and the inherent seasonality of sheep production to a growing list of reasons for the observed declines. A study by Stillman et al. (1989) indicated that returns to sheep enterprises have historically been positive, but the authors suggested still higher returns may be needed to compensate managers for additional management skills needed in sheep and for the extensive labor requirements. A U.S. International Trade Commission study (1991) concluded that demand for lamb and mutton is lower than demand for competing meats. It also suggested that the economic returns to farmers and ranchers may be lower for sheep than other livestock or crop enterprises.

Purcell et al. (1991a) reported the results of a national survey designed to analyze supply responses in sheep. Profitability and revenue flows were found to be important motivating factors among producers who had recently expanded flock size, but personal preference for sheep compared to other possible enterprises (livestock and crops) also ranked high. Labor costs/availability, droughts and poor profits were reasons given by producers who had reduced the size

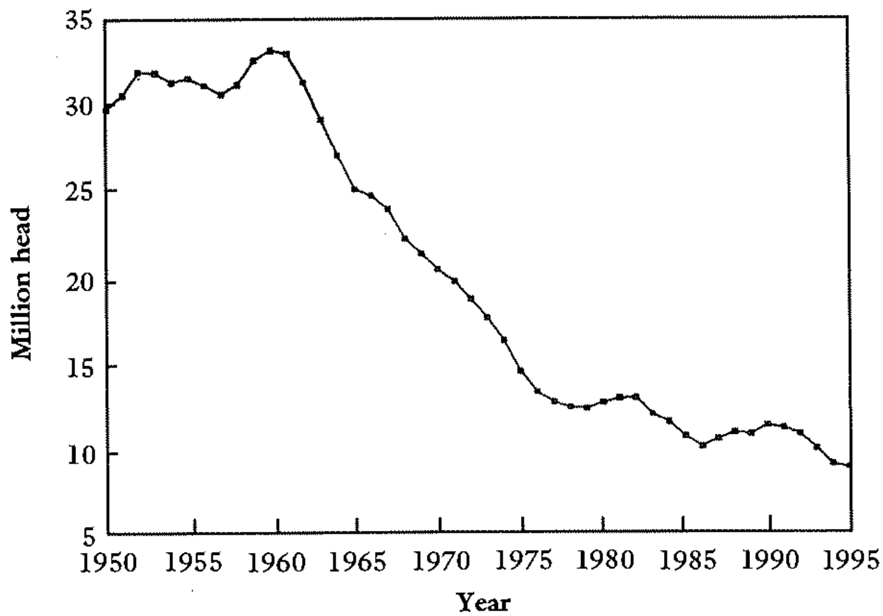
[1] Professor, Agricultural and Applied Economics; and Director, Research Institute on Livestock Pricing, Virginia Tech, Blacksburg, VA 24061.

of their operations. Limits on available acreage, especially properly fenced acreage, and financing were found to constrain expansion plans for those who wanted to expand.

Purcell et al. (1991a) concluded that the supply response function in sheep production is not symmetric. Getting out of the business or downsizing is relatively easy, but subsequent increases are not – even when lamb/wool prices are attractive. The authors conceptualized the supply response function as shown in Figure 2. If a producer is at point A, reducing quantity when prices drop from P_A to P_B and moving to the lower quantity at point B is relatively easy. If prices for lambs then increase to level P_A again, the "response path" is more like BC, not BA. Labor, even part-time labor, that was dismissed in moving from A to B may no longer be available. Pastures that were adequately fenced at A may no longer be adequate. Equipment has become outdated and buildings have been converted to other uses. A "ratchet effect" is present and the supply response path for rising prices is not the same as that for falling prices. Once industry size has been reduced, it is difficult to regain the lost capacity even if selling prices improve.

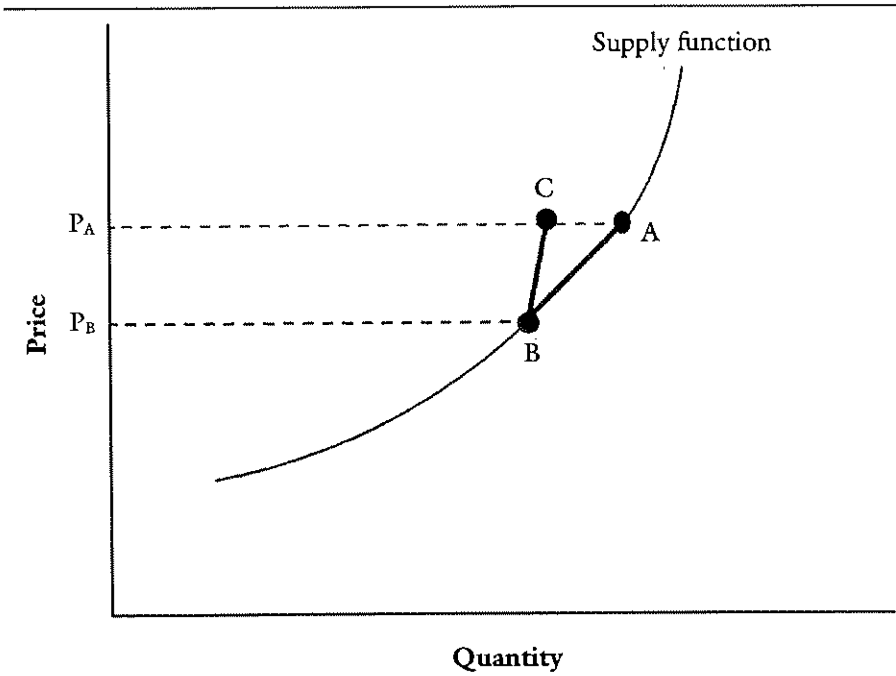
Obviously, quite plausible empirical and conceptual reasons for the decline in the industry can be presented. Underlying every reason presented, however, is a truism: profitability has been inadequate to keep resources in sheep production. Labor could be hired, fences could be built and acreage could be diverted from other enterprises if the economic incentives were sufficient. Figure 3 presents the dilemma. Monthly prices for Choice/ Prime slaughter lambs in the San Angelo, TX, market area are plotted from 1980 through 1994. Estimates of break-even prices differ across producers and are at least partly a function of wool prices, but sheep enterprise budgets suggest slaughter lamb prices of $60 per hundredweight or higher are needed to cover all costs over time. If $60 is close to break-even, Figure 3 suggests producers have periodically received both large profits and large losses. The period since early 1990 has been especially difficult, however, with the monthly average prices dropping as low as $45.81 in February of 1991. The April 1994 price was $51.25, putting producers well below break-even prices again.

Figure 1. U.S. Sheep and lamb inventory (1950-95).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook*, USDA-ERS, various issues.

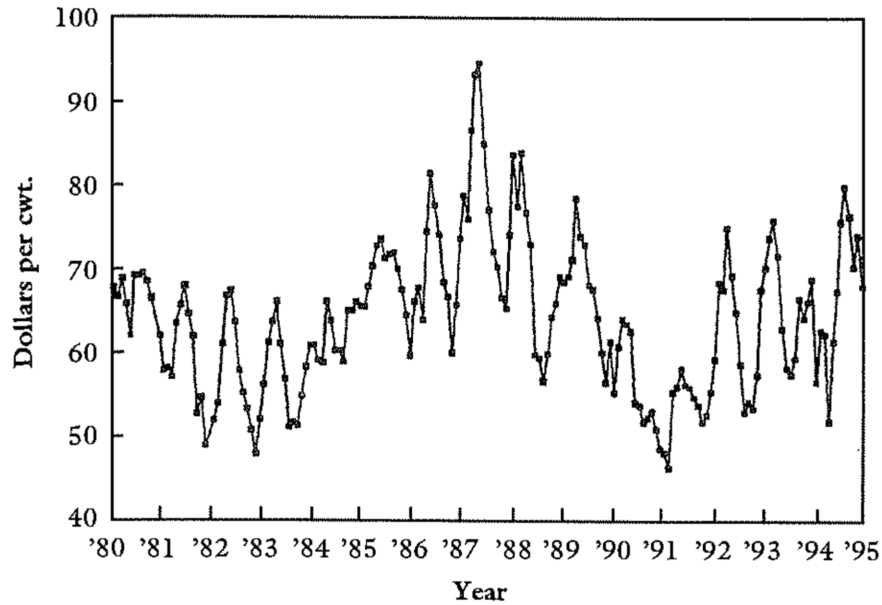
Figure 2. Conceptualization of asymmetric supply response paths in sheep production.[a]



[a] Adapted from Purcell, Reeves and Preston (1991), *Economics of Past, Current and Pending Change in the U.S. Sheep Industry with an emphasis on Supply Response.*

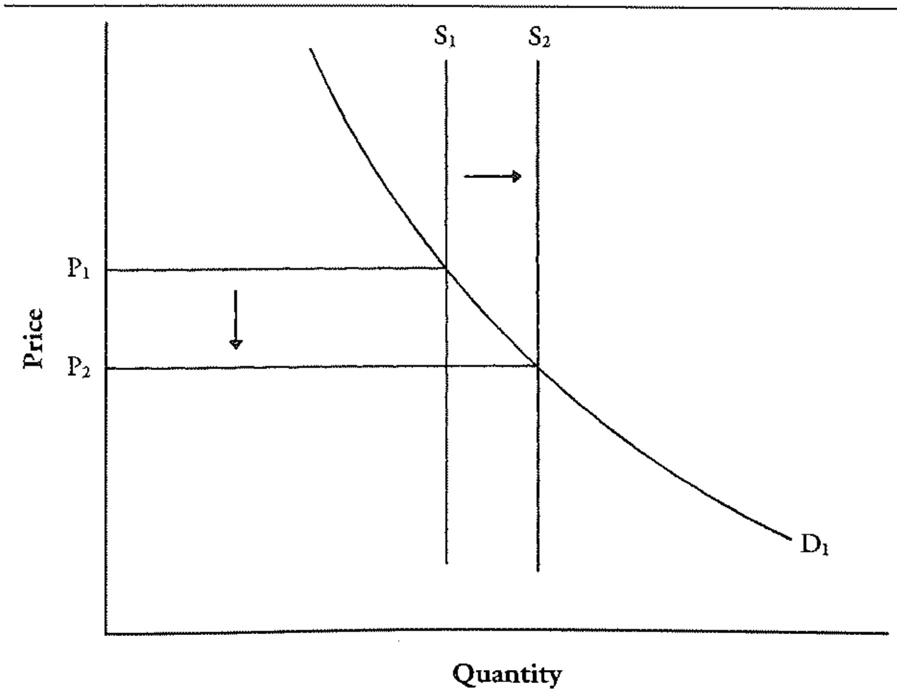
During recent years, the relatively low lamb prices and the pending loss of wool incentive payments – given 1993 Congressional actions – have apparently strained the convictions of even the staunchest sheep producer. The decline in inventories to below 9 million head on January 1, 1995, came in this setting, suggesting that another round of largely irreversible industry-wide declines has occurred.

Figure 3. Monthly slaughter prices, San Angelo, TX, market area (1980-94).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook*, USDA-ERS, various issues.

Figure 4. Demonstration of the price implications of an increase in supply with constant demand.



No agricultural commodity is consistently profitable. The saleable product from production is often undifferentiated and the producer is a price taker at the point of sale. With no significant barriers to entry, there is nothing to keep industry supply from expanding and driving costs below production. Corn prices reached $4.00 per bushel in 1973-75 after massive buying by the former USSR in response to its partial crop failure. In October 1986, cash corn prices of below $1.00 per bushel were recorded in Des Moines, IA, and the national average price for that marketing year as reported by the USDA was $1.50 per bushel – below costs for even the most efficient producer. Slaughter hog prices reached $60 per hundredweight on several occasions in the 1980s, only to be often followed by prices below $30 within 18 months thereafter. Break-even prices are currently near $40 for efficient producers, but cash transaction prices dropped below $30 in the last half of 1994. Weaned calf prices were, prior to 1987, typically below costs and the result was a liquidation of beef cow numbers from over 47 million in 1975 to near 33 million in the late 1980s. Producers have to accept, or "take," the price being discovered in the more aggregate (even world) market at any point in time.

Supply surges will always drive prices lower unless demand increases. The very low lamb prices in the early 1990s came at least partly because supply increased significantly and on a sustained basis relative to prior years. Demand for slaughter or feeder lambs (and most agricultural commodities) at the farm level is inelastic. A 1.0% change in quantity supplied will typically lead to a price change in the opposite direction that is greater than 1.0%. Figure 4 is a hypothetical example showing the basic economic forces that are at work. An increase in supply from S_1 to S_2 will, if demand is constant and the entire price-quantity schedule (the entire demand curve) does not shift from the position represented by D_1, drive lamb prices sharply lower – from P_1 to P_2.

Examination of data on commercial production of lamb and mutton suggests production levels during the 1980s and 1990s were and are variable in the short run, but they have not changed significantly in a longer-run context. Monthly production has been in the 25 to 35 million-pound range since 1980, and no sustained trend up or down is apparent (USDA-ERS, 1994). Since the mid-1980s, quarterly imports of lamb and mutton, always somewhat variable, have been mostly in the 10 to 15 million-pound range. Since 1987, data have been available on lamb separate from mutton and quarterly lamb imports exceeded 10 million pounds only in early 1993. It appears, then, that there has been no sustained and long-term increase in supply to push slaughter lamb prices lower. Yet inflation-adjusted prices have declined sharply. Figure 5 indicates that 1978 prices, expressed in 1982-84 dollars, would have been $100 per hundredweight. In 1991, a price below $40 per hundredweight was recorded, a decline of over 60% from the 1978 high when all prices are converted to a 1982-84 base to allow legitimate comparisons over time (USDA-ERS, various issues).

Clearly, there are reasons other than changes in supply for the decline in prices and the continued disinvestment that is documented by the decline in sheep inventory numbers. The objective of this article is to explore what is happening in the industry, to look for the "why" of the price declines and to offer guides to longer-term strategic efforts to restore profitability and growth to the lamb sector.

Economic Sources of Price Pressure

Prices can and will come under pressure for various reasons. As shown in Figure 4, shifts in supply such as that from S_1 to S_2 will always put pressure on prices. But, as suggested earlier, the data show that neither U.S. nor imported supplies are increasing significantly in the long run. The other possible sources of downward price pressure are: 1) expanded marketing margins at the processing or retailing levels in the presence of stable demand; 2) decreases in demand at the consumer level; or 3) some combination of 1 and 2.

Marketing Margins

A marketing margin or price spread refers to the differentials between retail level and farm level prices. In terms of basic economics, it is $P_R - P_F$ in Figure 6. Price P_R is established at the retail/consumer level by the intersection of supply and retail-level demand. The price P_R is the only price at which the quantity being offered by the system (the short-run supply, S_1) matches the quantity consumers will take given the retail-level consumer demand (labeled D_R). The demand at the farm level, denoted by D_F, is a derived demand that is tied to demand at the retail level. In practice, the price paid for slaughter lambs (P_F) by a middleman who is converting slaughter lambs to fresh lamb products is generated by:

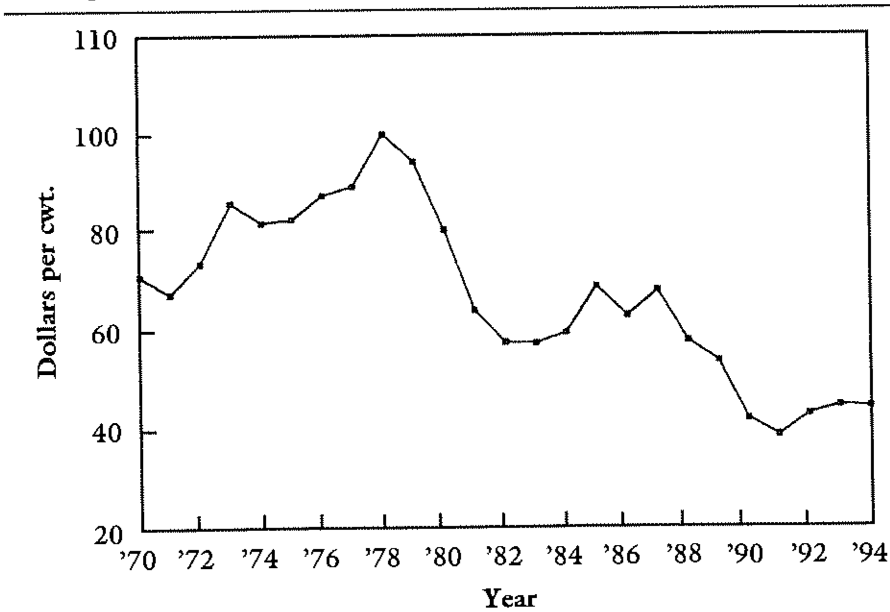
$$P_F = P_R - (COST + MAR)$$

where P_F = farm-level price for slaughter lambs; P_R = retail-level price for lamb; COST = the middleman's cost of operation; and MAR = a margin the middleman seeks to extract to generate an acceptable return on investment.

Given this simple but realistic development, downward pressure will be placed on farm-level prices (for given retail prices) if the middleman's costs increase and/or if the margin extracted increases. Personal interactions with packers/processors suggest that they think in terms of a gross margin per head. For given values in boxed lamb or packaged products, they calculate the maximum price they can pay for slaughter lambs and still earn the targeted gross margin per head. As they seek to locate and buy lambs for the weekly slaughter, buyers may not always be able to get the lambs bought at the target-driven price. But, over time, that target margin will be extracted or the investment will eventually be shifted to some other economic use.

The other possible source of pressure on producer-level prices from the marketing margin is increased costs. If the processor's costs go up over time, there will inevitably be pressure on slaughter lamb prices. Since per-unit costs of processing are in part a function of the level of efficiency achieved, the progressiveness of the middlemen in investing in new technology will be very important to the economic health of the entire sector. A simple and

Figure 5. Inflation-adjusted (CPI; 1982-84 = 100) yearly average lamb prices, San Angelo, TX (1970-94).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook*, USDA-ERS, various issues.

widely used barometer of efficiency at the middleman level is the price spread. If there is a reason to expect competition to place constraints on the margin that can be extracted and to keep profits roughly the same over time, then any changes in the price spread are due to changes in costs.

Figure 6. Demonstration of retail and farm-level demand and the implicit marketing margin.

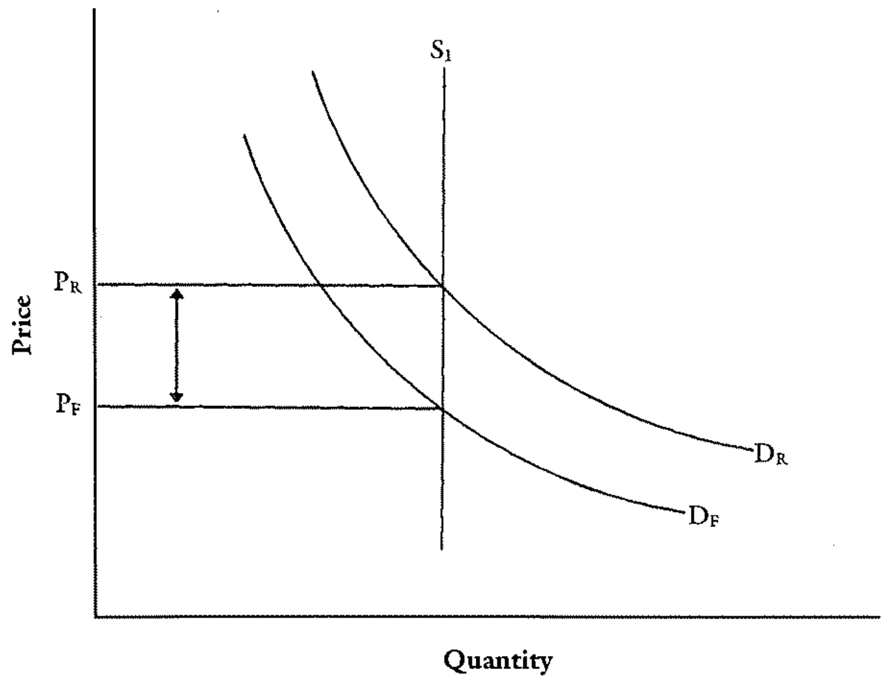
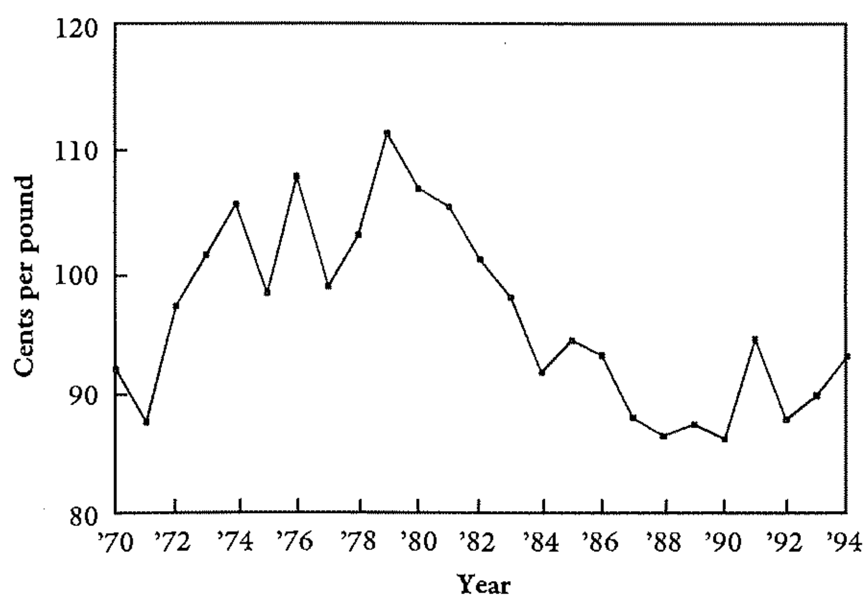


Figure 7. Inflation-adjusted (CPI; 1982-84 = 100) farm-retail price spread for Choice beef (1970-94).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook*, USDA-ERS, various issues.

A look at price spreads in competing meats is instructive. Figure 7 shows the real or inflation-adjusted (Consumer Price Index [CPI]; 1982-84 = 100) farm-retail price spread for Choice beef across recent years. The spread has declined over time, especially in the first half of the 1980s. The decline means either: 1) beef packers are accepting a lower operating margin; or 2) their efficiency has increased significantly and costs have therefore declined. Available information on publicly traded companies such as Iowa Beef Processors (IBP) indicates it is not lower earnings. It appears, then, that costs have been reduced. Large firms in the beef industry, an industry that saw massive consolidation during the 1980s, have apparently become more efficient. They have more than offset price inflation in the inputs they must buy.

The increased efficiencies and cost savings in beef packing and processing appear to have come primarily from economies of size and from stabilizing the flows of cattle into slaughter and processing. Figure 8 shows a plot of the slaughtering costs by hourly operating levels as adapted from Ward (1988). Per-head costs are still declining at the rate of 325 head per hour. Ward suggests that there are comparable savings in the fabricating phases of the operation. His conclusions are supported by Duewer and Nelson (1987) who developed computerized estimates of costs by function and operating level (relative to capacity), and for single- and multiple-shift beef packing plants.

The second apparent source of cost reductions has been sufficiently important for the large beef packers to introduce "captive supplies" as a new way of doing business. By feeding their own cattle, having cattle fed for them and by contracting for cattle and controlling delivery dates, beef packers have been able to stabilize the flow of cattle into their facilities. Figure 9 shows why this is important.

At or near operating level A (the optimal or designed operating level), costs per head can be significantly below those at B. An in-plant chain designed to operate at 300 head per hour may require the same labor force and virtually all of the same costs if it is operating at 200 head per hour. If it costs $4,000 per hour to operate the line, the per-head costs are $13.33 per head at 300 head per hour and $20 per head at 200 head per hour. The savings extend through the fabrication functions. Kay (1993) reported an interview with IBP personnel in which there was indication that IBP believed it could save $15 per head in slaughtering and fabricating costs if the flows of cattle through a plant can be stabilized near optimum operating levels.

These basic economic relationships are important. They point to a market-based source of relief for the downward pressure on livestock producers' prices. It may well be that slaughter cattle prices in the late 1980s and into the 1990s have been higher, on average, than they would have been if the middleman efficiencies had not been realized.

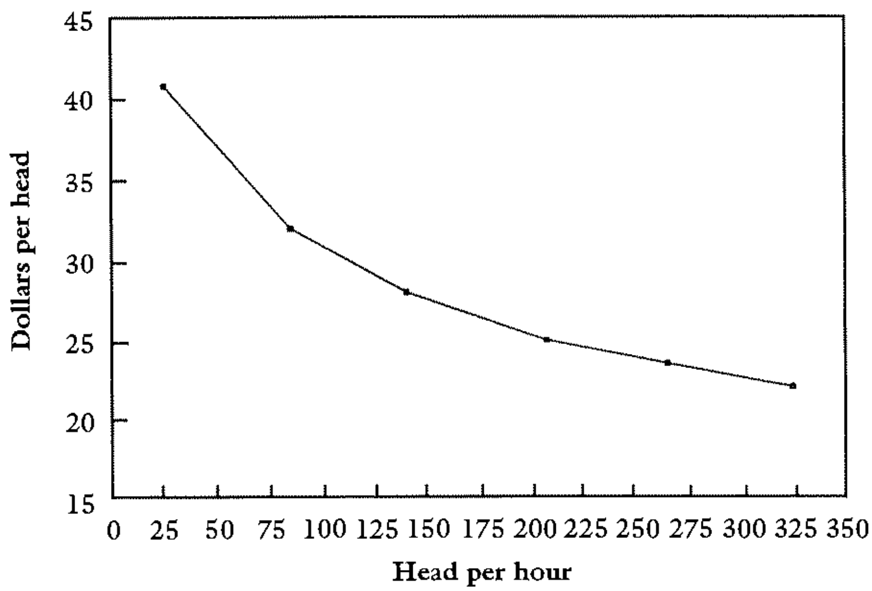
The performance of the price spreads in pork has not been as effective as in beef. Figure 10 shows inflation-adjusted spreads across recent years. The spreads worked higher during much of the 1980s. In the 1990s, however, there are some early indications that the move to larger processing firms is starting to have an impact. The spreads were showing signs of decreasing before jumping again in 1994.

Unfortunately, it is not possible to plot comparable spreads for slaughter lambs. The USDA stopped reporting retail lamb prices in 1981 and price spreads comparable to those for beef and pork require a composite retail price series for lamb. A less effective but revealing alternative is to calculate the ratio of retail to farm-level prices for selected cuts in beef and pork and to compare them to comparable ratios in lambs. Table 1 provides data and simple ratio measures.

Tracking prices for precisely the same cuts across the 15-year period is difficult, but basic comparisons are possible. In beef and in pork, especially beef, the increase in the ratio of prices is greater for an important cut (such as a rib roast) than it is for Choice beef as a whole. The composite retail prices for both beef and pork show modest increases relative to slaughter animal prices. The ratios for the specific cuts show bigger increases. The ratio for beef rib roast goes from 4.4 to 6.7, a 52% increase. The ratio for pork chops increases by 64%, going from 4.2 to 6.9. The ratio for lamb chops from the loin more than doubles, however, showing a 125% increase from 5.1 to 11.5.

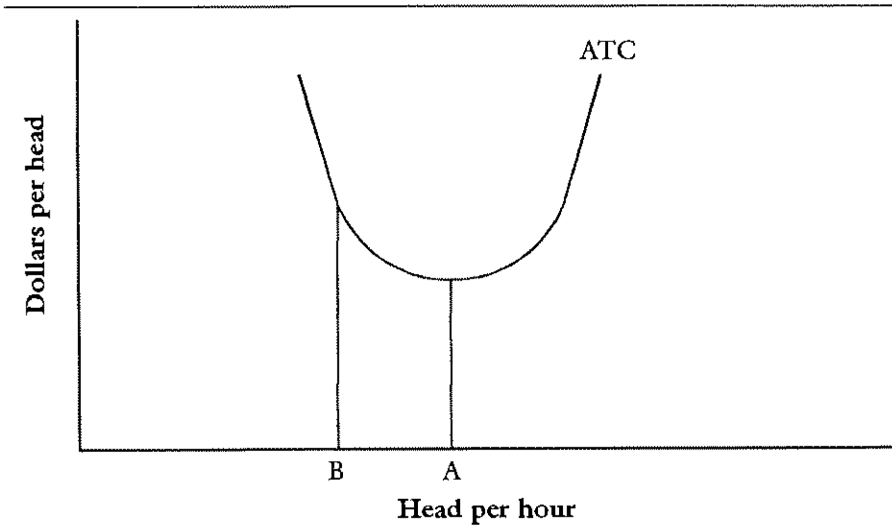
The Texas Agricultural Market Research Center (TAMRC) has estimated price margins using retail prices generated via econometric modeling of wholesale lamb prices after 1980. In the early 1980s, the farm-to-retail spread in 1982-84 dollars was around $0.50 per pound. In late 1990, the TAMRC study estimated the spread to be near $0.95 per pound. This is a 90% increase in the real or inflation-adjusted spread. In those same 1982-

Figure 8. Estimated costs of cattle slaughter by size of operation.[a]



[a] Ward (1988), *Meatpacking Competition and Pricing.*

Figure 9. Demonstration of the shape of the average cost curve by level of operation in modern livestock slaughter plants.



84 dollars, the TAMRC study suggests the farm-to-wholesale price spread decreased during the 1980s and ended the decade near 1981 levels at $0.12 to $0.14 per pound. The wholesale-to-retail part of the spread increased from $0.30 to $0.35 in the early 1980s to $0.80 in late 1990. It would appear that the spread between the wholesale or carcass level and the retail prices has been the source of the increases in the overall price spread for lamb. The TAMRC study suggests part of this increase might be explained by additional value-added further processing functions being taken over by middlemen. The relatively large increases in the price spreads are evidence of something less than high levels of technological progressiveness, however.

The analyses for lamb are simplistic, but the dramatic increase in the price ratios and the TAMRC estimates are informative. There is no apparent evidence that the large processing firms in lamb slaughter, where the CR-4 measure (percent of total industry business by the four largest firms) is now near 80%, are boosting slaughter lamb prices via increased efficiency and lower costs. The other possibility, of course, is that the retailer is extracting a large margin and/or the more valuable cuts like the lamb chop are having to "carry" the less valuable cuts and cover losses due to spoilage. But any such need to support the rest of the carcass was there in the late 1970s and early 1980s as well, so the price ratio comparisons should be legitimate. Whatever is the case, the lamb producer has a problem. Lamb prices were in the $60 range for both time periods examined and the lamb chop prices had increased from the $3.50 level to around $7 per pound between the late 1970s and the early 1990s.

Marketing margins or price spreads are not profit margins. Over time, as suggested above, the functions performed in the lamb marketing system can shift locations. The "marketing margin" that is extracted by the firm (the packer) that has added the breaking function to their duties should now be larger. The margin extracted by the retailer, who in 1995 seldom breaks the carcasses, should be smaller. One advantage of dealing with the total farm-retail margins is that these margins are not distorted by change in location of functions. But there is also an inherent disadvantage: it is not possible to know precisely where in the chain of events the problems of low levels of efficiency reside. There can be little question, however, that the lack of progressiveness and efficiency at the middleman level is one of the reasons the industry is in a state of decline. At retail, prices will be pushed up by inefficiencies relative to the competition; quantity consumed will therefore decrease and lamb products will lose market share as production declines and producers are forced out of business.

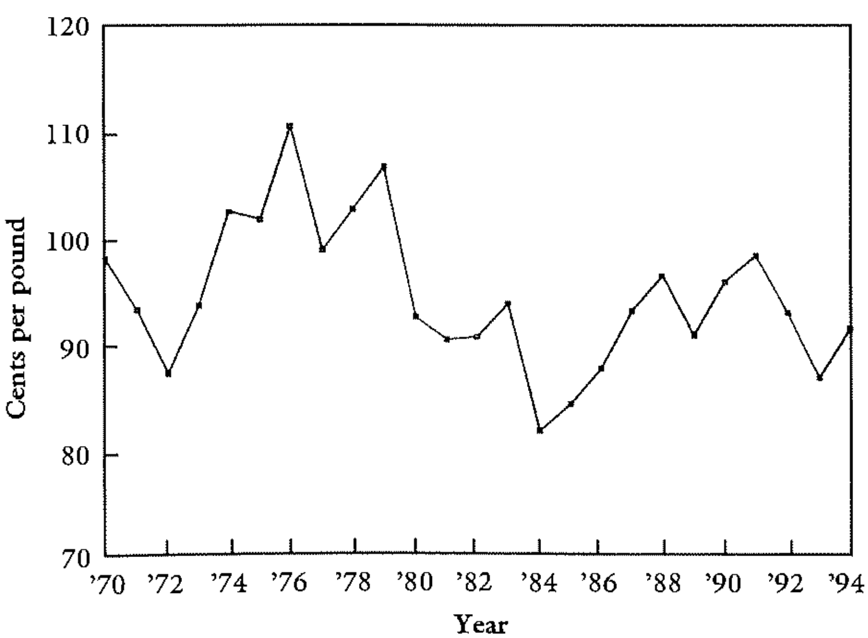
The look at marketing margins, price spreads and price ratios was completed assuming demand was constant. For a stable or constant level of demand, an increasing marketing margin will put downward pressure on price at the producer level, other things equal. But other things are seldom equal in the volatile lamb markets. Decreasing demand is another and very powerful source of downward pressure on producer prices.

Figure 11 demonstrates an important possibility. If consumer demand declines, which means the entire curve or price-quantity schedule shifts down and to the left from D_1 to D_2, then the retail-level price associated with a given supply S_1 declines from P_{R1} to P_{R2}. This shift in demand can and will make a significant difference. The derived farm-level price now becomes:

$$P_F^* = P_{R2} - (COST + MAR).$$

The new farm-level price (P_F^*) is below prior levels for given COST and MAR, because P_{R2} is below prior retail prices. Unless the marketing margin made up of operating costs and the firm's desired margin decreases (the preceding discussion suggests the marketing margin has actually increased), farm-level prices must go down. Earlier it was suggested that shifts in supply are the primary source of price changes within the year or even from year to year. If supply shifts are in fact the important short-run price mover, there is no doubt that demand shifts can be the important long-term price mover. The question immediately becomes: What

Figure 10. Inflation-adjusted (CPI; 1982-84 = 100) farm-retail price spreads for pork (1970-94).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook,* USDA-ERS, various issues.

has, in fact, happened to consumer-level demand for lamb over time?

Demand Shifts

In turning to an analysis of demand, the lack of retail price data for lamb complicates the issue. Another problem emerges when per capita consumption data are used in analyses. Like the other meats, per capita consumption of lamb is a disappearance figure generated by measuring production and beginning and ending inventories and bringing population into the calculations. In lamb, the numbers are often stable to the point of being static, with quarterly numbers near 0.35 or 0.40 pounds, depending on the decade being examined. Within-year differences between quarters are often 0.02 to 0.03 pounds or less. This lack of precision in measurement makes statistical analysis difficult.

Before looking at what can be done in analyzing demand for lamb in the presence of existing data problems, it is useful to look at a frame of reference and to examine a competing meat where data problems are not so severe. A useful framework is shown in Figure 12. For convenience, start at an initial price of P and a quantity being offered, often measured as per capita consumption, of Q. This price (P) and quantity (Q) may be the observed price and quantity for a particular year. Around that price/quantity coordinate, labeled R as a "reference point," four quadrants are constructed and labeled A, B, C and D. Movement from R into any one of the quadrants has an important message.

At any point in time, consumers will take a greater quantity only at a lower price. This law of demand gives a very important property to a demand curve – it has a negative slope. Visualize a negatively sloping, usually slightly convex, curve passing through the point R in Figure 12.

Any price/quantity coordinate or combination that falls on that curve is on the same level of demand. Observers of the meat trade will often say "demand is good this week" when they have seen an unusually large number of loads being moved. But is that observation correct? Is quantity the only thing that matters? What about price? Did price decline sharply? To examine the level of demand, you have to look at both price and quantity. Taking a larger quantity at a lower price is just picking another price-quantity combination from the schedule of price-quantity combinations along a single demand curve. It is not a change in the level of demand.

Any move into quadrant A in Figure 12 is a change in demand. On the vertical through R that borders area A, a higher price is being paid for the same quantity; on the horizontal, an increased quantity is moving into consumption at the same price. Between the two extremes, both quantity and price are increasing. If you pick any point in quadrant A, it cannot be on and must be above the negatively sloping demand curve that passes through R. That point in A must be on a higher demand curve, another negatively sloping function that will be roughly parallel to the one that runs through point R.

The opposite reasoning applies to quadrant C. Price or quantity, or both, are declining. Intuitively, there are problems on the buying side if the only way consumers will take even a smaller quantity is at a lower price. Any point in C must lie on a negatively sloping demand curve that lies below and to the left of the one that passes through R. Moves from R into quadrant C mean demand has decreased.

In quadrants B and D, the answer to whether demand has increased or decreased is "it depends." Quadrant B

Table 1. Demonstration of various profit centers in the lamb production-marketing system, each with an implicit and largely independent profit objective.[a]

Item	Price, $/pound	
	Quarter 1, 1978	Quarter 3, 1993
Beef:		
Retail choice beef	1.86	2.92
Rib roast	2.09	4.94
Slaughter steers	0.48	0.74
Pork:		
Retail pork	1.42	2.00
Pork chops	1.98	3.31
Slaughter hogs	0.47	0.48
Lamb:		
Lamb loin chop	3.48	7.03
Slaughter lambs	0.68	0.61

Item	Ratios, cut/(retail price ÷ live animal price)	
	Quarter 1, 1978	Quarter 3, 1993
Beef:		
Retail choice beef	3.9	3.9
Rib roast	4.4	6.7
Pork:		
Retail pork	3.0	4.2
Pork chops	4.2	6.9
Lamb:		
Lamb loin chop	5.1	11.5

[a] Calculated from data in USDA-ERS, Livestock and Poultry Situation and Outlook Reports and from data (1993 lamb loin chop) provided to American Sheep Industry, Inc., from a private firm which records retail prices.

is the more important one given the move in that direction by poultry over time. Obviously there are some points in B that would lie above a curve through R and some that would lie below. To determine whether the demand surface has shifted, empirically generated elasticity measures have to be used. Determining, for any price-quantity point in B, whether demand has increased, decreased or is the same is not a difficult job but is not necessary for the discussion here.

Figure 11. Demonstration of the price implications of a reduction in consumer demand for lamb from level D_1 to D_2, supply holding constant.

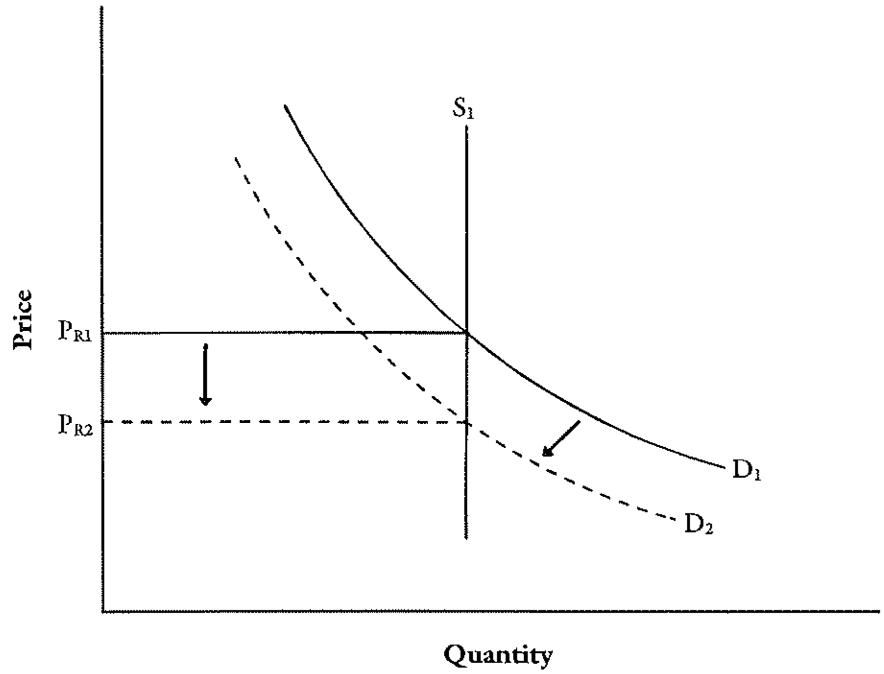


Figure 12. Framework within which to think about changes in the level of demand from a particular price/quantity combination, R.

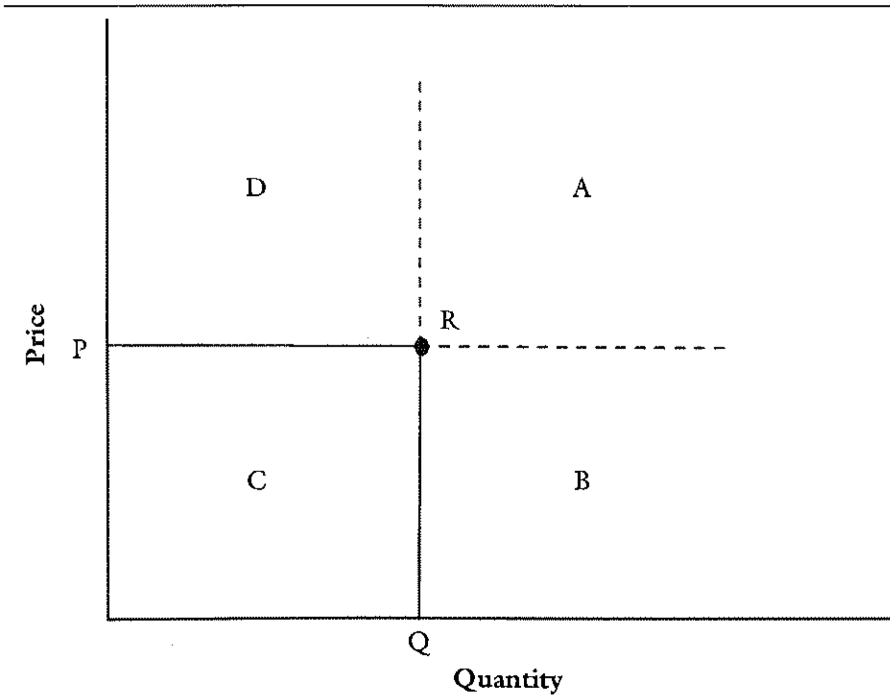


Figure 13 shows a long-term plot of deflated or inflation-adjusted Choice beef prices and per capita consumption. In the 1960s and into the 1970s there tended to be periodic moves up and to the right from any yearly (the numbers are the years) price/quantity coordinate picked. This is comparable to a move into quadrant A in Figure 12 and is evidence of increasing demand. Since all of the prices have been adjusted for the influence of overall price changes (CPI; 1982-84 = 100), it is legitimate to compare across years. The demand surface was shifting up and to the right in the 1960s and 1970s.

In 1979, the economic world changed for beef. Note the price decline of over 30% by 1986 with per capita offerings essentially constant near 77 to 78 pounds. This is equivalent to moving down the vertical in quadrant C in Figure 12. Since 1986, prices have held at relatively constant levels, but per capita quantity offered (and therefore consumed) dropped by over 10 pounds through 1993 before increasing significantly again in 1994. A negatively sloping demand curve passing through any of the yearly points since 1979, with the possible exception of 1987 and 1988 and then 1993 and 1994, must be below the demand curve for the prior year. That means demand decreased each year. After cattle inventories peaked above 132 million head in 1975, the demand-side problems pushed numbers well below 100 million head to just above 95 million in 1990 before numbers stabilized and started to show modest year-to-year increases. From a beef cow herd that was above 45 million head in 1975, a reduction of more than 12 million head was forced by a marketplace seeking to restore a balance between supply and decreasing demand.

Turning to lamb, Figure 14 provides a plot of commercial production of mutton and lamb and deflated prices of lamb at retail from 1970 through 1980, the last year the USDA released retail lamb prices. There is evidence in this plot of demand problems. As suggested earlier, demand has a property called elasticity. Technically, elasticity is the percent of change in quantity divided by the percent of change in price. Research efforts have concluded that demand for lamb at the retail level is inelastic which means the ratio is less than 1.0 in absolute value (Byrne et al., 1993; Purcell, 1989). Most empirical estimates are near –0.6. Using the –0.6 estimate allows an analysis of what was starting to happen to demand for lamb in the 1970s.

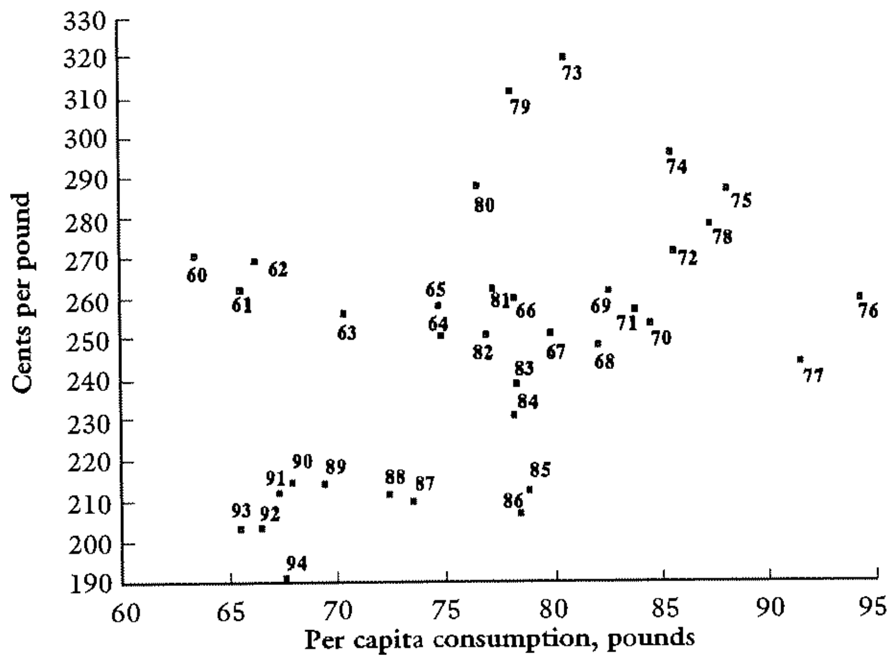
Consider 1976 for a demonstration of the demand issues. Production was 361 million pounds and the deflated retail price was $3.26 (326 cents in the graph). Given the scales employed in the graph and using the –0.6 estimate of elasticity, the demand surface that ran through the price/quantity coordinate for 1976 had a negative slope of about 55 to 60°. The coordinates for 1977 are clearly down and to the left, the equivalent of a move into quadrant C in Figure 12.

Using the demand elasticity coefficient of –0.6, the 5.5% reduction in production from 1976 to 1977 would have prompted a 1977 price 9.2% higher, generating a price of $3.56 if demand in 1977 had been the same as in 1976. But the 1977 price was only $3.08, not $3.56. There was a significant reduction in demand from 1976 to 1977. It appears that some additional slippage occurred during 1978 and 1979, but the 1980 coordinates are even more obvious if 1976 is still a "reference point." The demand curve in 1980 was down and to the left even more, indicating a continued decrease in demand.

The scatter plot does not tell us why demand was starting to decrease. Cattle and beef prices were in the middle of a two- to three-year upward surge in 1979 and 1980 and that change should have increased demand for lamb. The analysis by Byrne et al. (1993), shows a positive cross elasticity between lamb and beef, suggesting that beef is seen by consumers as a possible substitute for lamb. Increases in the price of a substitute (beef) should increase the demand for the base product (lamb).

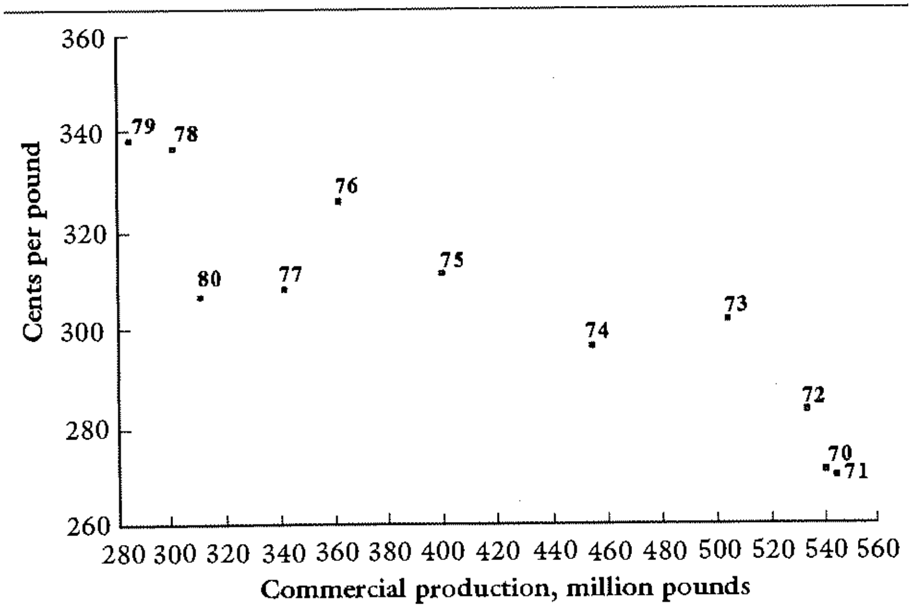
The probable explanation for the decline in demand for lamb lies in the taste and preference demand shifter. It was in the 1979-80 period that demand for beef (and pork) started a long-term decline because of increasing consumer concerns about

Figure 13. Per capita consumption (retail weights) and deflated retail prices (CPI; 1982-84 = 100) for Choice beef (1960-1994).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook*, USDA-ERS, various issues.

Figure 14. Commercial lamb/mutton production and deflated (CPI; 1982-84 = 100) retail prices of lamb (1970-1980).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook*, USDA-ERS, various issues.

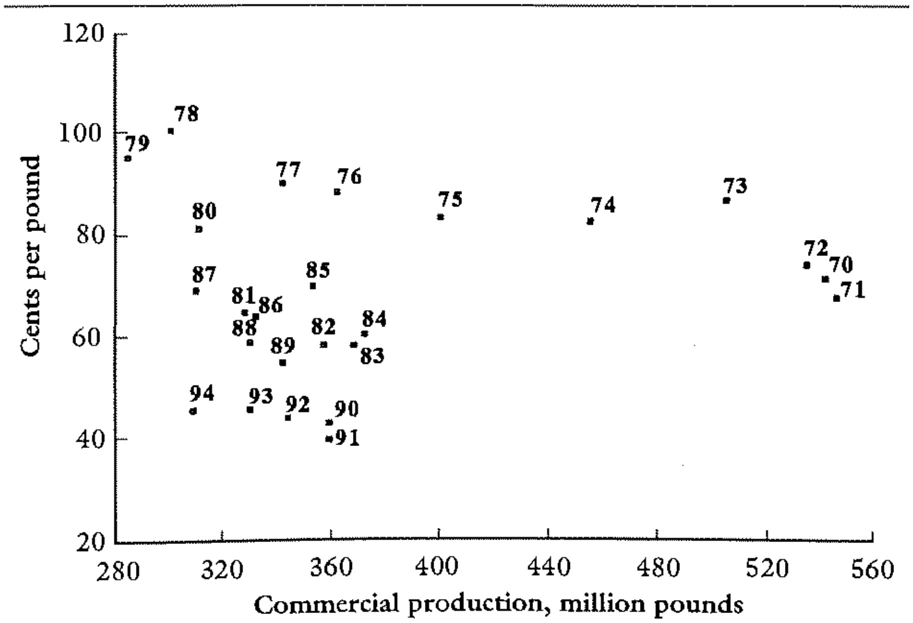
fat and cholesterol and increasing demands for consistent quality and convenience in preparation. Surveys taken during the 1990s continue to show these same concerns for the red meats (Purcell, 1991b, 1993a,c) while poultry, viewed more positively by consumers, enjoyed the powerful pull of increased demand and gained a larger share of the total meat market in the U.S.

Figure 15 shows a plot of deflated slaughter lamb prices for the San Angelo, TX, market area and the same commercial production used in Figure 14 extended through 1994. Retail lamb prices were not available after 1980. The decline in demand for lamb from 1976 to 1977 was less dramatic at the farm level than in the retail price plot, but the dramatic decrease from 1976 to 1980 is again apparent when live lamb prices are used. The 1994 price-quantity coordinate would fall on the lowest (and farthest to the left) of any negatively sloping demand surfaces that could be superimposed on the graph.

Examination of the demand for lamb, then, suggests that declines in demand are the source of much of the long-run economic pressure that is forcing lamb prices down and pushing producers out of business. The demand for slaughter lambs running through 1994 in Figure 15 is a derived demand, derived from the consumer's willingness to pay at the retail level. There appear to be efficiency problems at the processing or retailing levels which are expanding the marketing margins and putting even more pressure on farm-level demand. But that development, while important, should not be allowed to conceal the truly important conclusion: Decline in demand for lamb at the consumer level is the primary continuing problem in the lamb industry in the mid-1990s.

The demand problems must be corrected if the industry is to stabilize and establish a base on which it can grow. The lamb industry is now passing through a phase during which the marketplace is slowly, inevitably and painfully moving toward restoration of an equilibrium – in a much smaller industry. If the demand-side problems are not more effectively addressed, this pattern will continue. Lamb prices will be constant to lower, down significantly in inflation-adjusted terms during the rest of the 1990s, and more producers will be forced out of business.

Figure 15. Commercial lamb/mutton production and deflated (CPI; 1982-84 = 100) slaughter lamb prices (1970-1994).[a]



[a] *Livestock, Dairy and Poultry Situation and Outlook,* USDA-ERS, various issues.

An Industry Agenda

From a vantage point of early 1995, the first need is widespread acceptance by industry leaders that there are, in fact, major demand problems. The national commissions and councils and the leadership positions in the states are made up primarily of producers. History has clearly shown it is difficult for those involved in the production of a product to accept that consumers find fault with that product. The beef sector has struggled with this inherent barrier. There are now over 70 recognized breeds of cattle in the U.S. and informed observers suggest that quality variability is worse today than it was 10, 20 or even 30 years ago. A 1991 survey indicated consumers encounter what they consider to be eating quality problems at nice restaurants 32% of the time, on average, when they order beef (Purcell 1991b).

The examples extend beyond foods. In the 1970s, U.S. car makers refused to accept the reality of what buyers were clearly telling them – U.S. cars no longer fit the mold of what buyers wanted. Eventually, the car makers adjusted, but only after imports took a bigger part of the market.

Incredibly, giant IBM fell victim to the malady of refusing to accept that its product and service lines were diverging from the needs and preferences of computer customers. The home of the original "personal computer," IBM has lost huge hunks of a market it once dominated.

There are lamb producers who see the problems. That recognition was apparent in an unpublished "national needs assessment" conducted for the American Sheep Industry Association, Inc., (ASI) by the author in 1992. But scattered recognition and perception is not enough. Acceptance has to be widespread and has to run through all the commissions, councils and industry leaders.

Once acceptance of the economic realities is widespread, the next phase is one of understanding the nature of the problem. The problem is one of a continuing and growing divergence between the product offering in the supermarket and the needs and preferences of the modern consumer. The change will have to come in the product offering; the consumer will not change to close the gap. Educating the consumer is too simplistic as a solution and it is not the correct answer. It is important to understand that no amount of advertising will bring the affluent, well-educated, on-the-go consumer to a product offering that is characterized by a whole leg of lamb and a lamb chop that appears to be high in fat. The leg requires carving and preparation skills the typical modern food shopper under the age of 50 does not have and is not interested in acquiring. The fillet of chicken breast in the poultry counter requires none of those skills – and it is pre-cooked, marinated and ready for the microwave. Many consumers will not even notice that, when converted to a per-pound price, the chicken breast fillet is $5 to $8 per pound. Fresh lamb offerings are seriously outdated and must be changed.

The importance of the product offering is clear in consumer surveys. Purcell (1993b) found only half of 387 respondents answered "yes" to the question, "Does the price of lamb strongly limit the amount you purchase?" The higher-income, better-educated food buyers who worked full-time outside the home were even less likely to answer "yes." Well over half of 390 respondents answered "yes" to the question, "Would you buy more lamb if it were in more convenient forms?" The better-educated consumer who works full-time outside the home was more likely than the average respondent to answer "yes." Over 300 of 391 respondents indicated they would try free lamb recipes if they were available, a response pattern that indirectly addresses the fact that many consumers do not know how to prepare lamb.

The evidence is available. The product offering must change substantially in order to deal with the issues surrounding fat levels, cholesterol, quality (and consistency) and convenience in preparation. Close external trim on a loin chop that still appears by visual inspection to be at least 25% fat is not a substantive change in product offering. A reformulated and perhaps flavor-enhanced product in the shape of a loin cut that is 90% or 95% fat-free would be a substantive change.

If the needed understanding is present, the next step in the process is a perception phase. Having accepted the reality of demand problems and having developed an understanding of the nature of these problems, the perception phase deals with why the problems have not been corrected. The answer may be found in the way the lamb marketing system is structured and the related lack of economic incentive at the individual-firm level.

Figure 16 provides a simple but useful frame of reference. It suggests four distinct, separate and independent-thinking profit centers between the original seedstock producer and the consumer. These could be, as suggested: 1) a commercial producer of slaughter/feeder lambs; 2) a lamb feeder; 3) a packer/processor; and 4) a retailer. To be "consumer driven" and responsive to the consumer, each of these separate profit centers has a clearly definable task: It must perform its economic function in such a way as to ensure the consumer's needs and preferences will be met. The firm may have to adjust how it has traditionally operated to make a maximum contribution to that final consumer product. That adjustment may be counter to the long-standing way of doing business as an independently-thinking profit-maximizing firm, however, and herein lies a major problem.

The reality is that any one of the independent-thinking profit centers in the sheep industry will be reluctant to accept a role where contribution to the needs of the entire system is first in importance. Each tends to maximize profits with an eye toward the quarterly profit and loss statement and with little regard for how well their link fits in the chain of events needed to meet the preferences of a changing consumer. Feeders may carry lambs to heavy weights because the marginal return of the last pound of gain still exceeds its marginal cost (and the price system does not stop such practices). Packers buy on dressing percentages, and yield grades (YG) are ignored or treated in an asymmetric fashion with discounts on YG4s but no premium on YG2s. There is no effective "pricing to value" system. The producers get all the wrong signals, the product is too fat and the performance of the system as a whole is poor at best. And the system is essentially devoid of any investment in its collective future. A pittance relative to needs is spent on market and product development, the industry gets smaller and producers are forced out of business by low prices.

The "profit center syndrome" is not unique to lamb. What it brings is a reluctance to make the needed investments at any particular level in the system. Feeders try to extract a margin

Figure 16. Prices and ratios of retail-to-live prices for beef, pork and lamb.

Consumer
Profit Center 4 (Retailer)
Profit Center 3 (Packer/Processor)
Profit Center 2 (Lamb Feeder)
Profit Center 1 (Commercial Producer)
Seedstock Producer

by buying feeder lambs at as low a price as possible and contracting with the packer. Packers buy on dressing percentage, ignore cutability differentials and impose a price slide or an absolute cut-off point at some specific liveweight. Retailers are largely passive, treating the lamb offerings as a minor part of the total meat program. In this environment, everyone just tries to extract a margin. There are no proactive investments in know-how and technology to change the product offering.

Investments in market and product development are risky. In a commodity product like lamb with no branding of fresh product, those investments are even more risky. Even if packers or value-added processors make the investment and generate a new product that works, there is no obvious way for them to capture and retain the benefits. Brand names help control and capture those benefits in poultry and the needed investments in product development are starting to emerge in pork as the large processors start to control genetics, get the quality variation under control and move to establish brand names for fresh pork. None of these conditions are widespread in lamb, and the investments in an industry-wide agenda of needs are not likely to come from the various profit centers as they currently exist and operate. The message is loud and clear: It is the producers and producer groups that are concerned about the long-range viability of their industry and it is the producers that will have to prompt the needed changes.

What the efforts are called that must be initiated by producer groups does not matter. The terminology "strategic alliance" is in vogue and that terminology is acceptable. The needs are what is truly important. The problems of lack of coordination that permeates the lamb marketing system from bottom to top must be corrected. Since those problems have persisted in the price-oriented exchange systems for decades, the possibility of moving to non-price means of coordination has to be examined. Obviously, there is no self-correcting mechanism in the price-based exchange system to generate the needed changes. The TAMRC study identified this lack of coordination as an important problem but was unable to address effectively how the problem could be solved.

This is not the correct forum to delineate in detail what should be done, but basic issues can and should be discussed. The details will have to come later and the details need to be developed by those with an inherent interest in the future of the industry. First and critically important, producers must ensure coordination between the production and processing phases. The preferred approach is to negotiate a working relationship with existing packers, a relationship built on the recognition of sharing increased net revenues in the short run and the building of a more viable industry in the long run. The short-run benefits can come from the reduced slaughtering/breaking costs associated with producers' efforts and new-found willingness to work with the packer in scheduling lambs into the plants. Lamb feeding (and lamb feeders) will also have to be involved as efforts are made to stabilize the numbers of desirable lambs throughout the year since seasonality is always a problem. There has to be something in it for everyone, but the cost savings can be significant and an economic base upon which coordinated efforts can be justified and partially financed is present. *Beef Today* magazine (1993) provides detailed coverage of a strategic alliance in beef that reached from the producer to the retailer. The program's participants obviously found that coordination can both decrease costs and increase values.

Long-run benefits come from being able to "price to value" within a coordinated system and get the right signals to commercial producers and seedstock producers. Also, there are the immensely important benefits associated with moving, over time, toward a more consumer-friendly product offering. The producer/processor functions must be in line with those needs. Increasingly, the retailer will be looking for a case-ready product and the value-added further-processing sector will have to be in a position to provide it as a reliable supplier throughout the year. The primary long-range benefit will come from a revised product offering, and a coordinated approach can ensure that needs are clearly communicated to the producer, that the "right" lambs will receive a premium and that everyone who participates can benefit.

An obvious and related need is to get a retailer or retail chain involved. Negotiations for net rather than gross margins are needed, and the primary objective of the effort being coordinated by producers is to put the retailer in a "can't refuse" position. A changed product offering with appealing point-of-purchase merchandising will get the attention of the manager of a meat department or store, especially if it comes at essentially zero marginal cost to the retailer. It is important that the retailer be viewed as a passive to neutral participant at best – there will be little or no incentive to force change coming from retailers. Retailers sell space and they will typically not care whether the space is occupied by chicken, pork, seafood, lamb or some non-meat item that their consumers want. They will have to see clear benefits to a more appealing and/or expanded lamb offering, and putting an attractive overall program in front of them is the correct approach. The right program will please their existing lamb customers and has at least some potential to bring new customers into the store over time.

Capital will be needed to get started. Once launched, the program may essentially finance itself. The cost savings from coordinated functions alone have been enough to prompt business arrangements and strategic alliances in other meats and non-meat food items and in the manufacturing sector of the U.S. economy. A part of those benefits could be and should be reinvested in the lamb industry to finance market and product development work and to help restore economic viability in the long run. But the importance of adequate initial capital cannot be over-emphasized. As producers and producer groups form local or regional alliances, it is very important that a "capital-raising" strategy be an initial and important part of the strategic planning process.

Conclusions

The opportunity is here; the time to act is now. In an industry configured the way it is in early 1995, the price-oriented lamb marketing system has failed leading to a gradual but persistent demise of the U.S. sheep industry. While pricing has allowed the consumer-level product offering to diverge in a dramatic way from what the modern consumer demands, it has not yet provided a system characterized by pricing to value, nor has it generated coordination between the technically related stages in the system. Efforts to force the current pricing system to work, by the coupling of quality and yield grading, are ineffectual. Attention needs to be focused on the needs for increased efficiency and technological advancements at the processing levels. Price spreads have apparently increased significantly in recent years, pushing retail prices higher and farm-level prices lower. Improvement in this arena may be a necessary condition to a return to economic viability for the industry.

Producers and producer groups need to turn to non-price means of achieving coordination before the industry either further integrates vertically, which threatens the future of the independent producer, or becomes so small it will no longer be an industry of the scope and function of the industry of recent decades. A critically important part of that new industry agenda should be a concerted and coordinated effort to change the product offering to more nearly align what is offered with the needs and preferences of the modern consumer. This is the sufficient condition for long-run economic viability of the industry. It is a tautology that the only source of financing for a return to a growth industry is the consumers' food dollars, and the competitive battle for those dollars is increasingly intense. The sheep industry will lose that battle unless significant changes are made in the marketing of, and markets for, lamb and lamb products.

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Effect of Fishmeal on Growth and Carcass Traits of Finishing Lambs[1,2]

M.K. Neary[3], M.J. Cecava[4] and E.P. Berg[3]

Summary

Forty-eight wether lambs were fed pelleted, grain-based diets differing in source and level of crude protein (CP). Diets contained either soybean meal (SBM) or SBM plus fishmeal (SBM + FM) at levels of either 13% or 16% CP on a dry matter basis. Lamb average daily gain (ADG), feed intake (FI), feed to gain ratio (F:G), total carcass lean, percent carcass lean, leg lean, yield grade (YG) and ribeye area (REA) were used to evaluate treatment effects. Source of dietary CP had no effect on any of the response variables. Level of CP fed did not influence ADG, FI or F:G. Lambs fed 16% CP diets tended to have carcasses with increased total lean (P = 0.14), increased percent lean (P = 0.07) and a more desirable YG (P = 0.19) than lambs fed 13% CP diets. Because the source and level of dietary CP had only small effects on lamb performance or carcass traits, producers should use economic considerations when choosing ingredients for finishing lamb diets.

Key words: lamb, fishmeal, carcass composition, protein level.

Introduction

Fishmeal is a protein source with low ruminal degradability (National Research Council [NRC], 1985; Hassan and Bryant, 1986; Hussein and Jordan, 1991b). Fishmeal can increase ruminant animal performance if metabolizable protein is limiting and the balance of amino acids undegraded from dietary protein is complimentary to protein from microbial origin. However, responses by growing lambs to fishmeal supplementation as reported in the scientific literature has been inconsistent.

Adam et al. (1982), Beerman et al. (1986) and Hassan and Bryant (1986) have shown that fishmeal supplementation of lambs can increase growth rate and improve feed efficiency, whereas Folman and Eyal (1978), Pond (1984), Umberger et al. (1988) and Hussein and Jordan (1991a) have reported no advantage for fishmeal supplementation compared with vegetable protein supplementation. Hassan and Bryant (1986) reported that fishmeal supplementation has been shown to increase nitrogen digestion and retention. Beerman et al. (1986) found that lambs supplemented with fishmeal had increased carcass muscle deposition.

Lambs used in our experiment were expected to be well above industry averages in regards to performance (ADG, F:G) and carcass composition (Berg et al., 1994b). The objective was to determine effects of fishmeal at two levels of dietary CP on growth and carcass composition of Suffolk wethers with a high potential for weight gain and carcass muscle deposition.

Materials and Methods

Forty-eight Suffolk wether lambs were fed one of four diets during a six-week finishing trial. Diets differed in CP level (13% vs. 16%) and source of supplemental protein. Source of supplemental CP was either solvent extracted soybean meal (SBM) or soybean meal with menhaden fishmeal (SBM + FM). When fishmeal was included in the diet, it was added at a rate of 3% of dietary dry matter and provided 12.5% to 15% of total dietary CP.

Treatments were: 1) 13% CP with SBM; 2) 13% CP with SBM + FM; 3) 16% CP with SBM; and 4) 16% CP with SBM + FM. Response variables to evaluate dietary treatments were: average daily gain (ADG), feed intake (FI) and amount of feed required per pound of gain (F:G). Response variables to determine effects of treatment on lamb carcass traits were: total carcass lean, percent carcass lean, amount of leg lean, USDA yield grade (YG) and ribeye area (REA).

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[2] Journal paper No. 14596, Purdue University Agriculture Research Programs.

[3] Department of Animal Sciences, Purdue University, West Lafayette, IN 47907.

[4] Research and Technology Center, Decatur, IN.

Ingredient composition and calculated chemical composition of diets are contained in Table 1. Diets were pelleted and consumed by lambs on an ad libitum basis using self feeders. Feeders were checked daily and feed added as necessary. Feed refused was weighed once weekly to determine lamb FI.

Lambs were shorn, treated for internal parasites and vaccinated against clostridial diseases before the study began. Lambs were housed three to a pen at the Purdue University Animal Sciences Sheep Research Center. Each dietary treatment had four pens of lambs for a total of 16 pens. Flooring was expanded metal and each pen measured six feet square and contained a nipple watering system.

Lambs were individually weighed once each week. Six lambs from each treatment were selected randomly for processing when average pen weight reached 115 pounds. No more than two lambs were selected from a single pen. Lambs were processed in accordance with approved procedures at the Purdue University Meat Science Laboratory. Kidney and pelvic fat were removed at the time of slaughter and discarded. Weights were recorded on warm pre-rigor carcasses.

Pre-rigor carcasses were scanned for total body electrical conductivity with an electromagnetic scanner (MQ-25; Meat Quality, Inc., Springfield, IL) before chilling. Carcasses were presented to the electromagnetic scanning chamber lying on the left lateral side as described by Berg et al. (1994a). Prediction equations used to determine total carcass lean and total leg lean were reported by Berg et al. (1994b).

Percentage carcass lean was determined by dividing total carcass lean by warm carcass weight. After a 24-hour chill, carcasses were cut between the 12th and 13th ribs and REA and FD were measured and recorded as an average of the two sides. The YG was calculated by the USDA formula: YG = 10(FD) + 0.4.

Performance data (ADG, FI, F:G) and carcass data were analyzed by analysis of variance using the general linear models procedure of SAS (1988) for a completely randomized design with a two-by-two factorial arrangement of treatments. A split-plot analysis was conducted with model sums of squares separated into effects of concentration of CP, source of supplemental CP, the interaction of CP level and source, weigh period (week) and the interactions of treatment and week. Pen was considered the experimental unit for analysis of performance data whereas lamb was considered the experimental unit for analysis of carcass data. Warm carcass weight was used as a covariant for analysis of total carcass lean, percentage lean, leg lean and REA. The effects of treatments on performance data were tested using pen nested within treatment as the error term. Treatment means were compared by the F-test protected Least Significant Difference method (Carmer and Walker, 1985).

Results and Discussion

One lamb died during the study and two lambs were removed due to rectal prolapse. Their data were included to the point where their condition appeared to be depressing performance.

Performance Data

Lamb ADG, FI and F:G are presented in Tables 2 and 3. Initial weights of lambs were similar for all treatments. Lambs on the study had a high potential for rapid growth as exhibited by the ADG of almost one pound per day, regardless of dietary treatment.

Level of dietary crude protein (Table 2) did not influence (P = 0.80) ADG of lambs. Feed intake of lambs was not affected by level (P = 0.84) of dietary crude protein. Because ADG and FI of lambs consuming either CP level diet did not differ, the F:G was not significantly influenced by the diet fed.

ADG (P = 0.89) and FI (P = 0.38) of lambs was not different regardless of the source of CP fed (Table 3). F:G of lambs did not differ due to dietary source of CP.

Hussein and Jordan (1991a) conducted two growing/finishing trials with crossbred lambs comparing various amounts of SBM and FM as supplemental protein. These researchers also reported that the inclusion of FM did not influence ADG, FI or F:G. However, they reported that lambs fed diets containing 14.9% CP had increased

Table 1. Composition of diets.

	13% CP		16% CP	
	SBM	SBM+FM	SBM	SBM+FM
Ingredient:[a]				
Ground corn	38.00	41.75	32.00	38.25
Oat mill by-product	38.00	34.50	37.25	38.25
Soybean meal, 48% CP	12.00	8.25	19.50	15.50
Rice hulls	5.50	6.00	4.75	3.75
Fishmeal	–	3.00	–	3.00
Molasses	2.50	2.50	2.50	2.50
Calcium carbonate	1.75	1.75	1.75	1.75
Salt	1.00	1.00	1.00	1.00
Dicalcium phosphate	0.50	0.50	0.50	0.50
Trace mineral premix[b]	0.25	0.25	0.25	0.25
Ammonium chloride	0.50	0.50	0.50	0.50
Chemical:[a]				
Crude protein	13.0	13.1	16.1	16.1
TDN	70.1	70.2	70.2	70.6
Crude fiber	11.0	10.5	10.7	10.4

[a] Percent of diet dry matter (DM).
[b] Heinhold Feeds, Inc., Kouts, IN.

ADG compared with lambs fed diets containing 13.3% CP. Pond (1984) fed Suffolk ram and ewe lambs (average weight = 72.6 pounds) diets containing SBM or SBM + 5% FM and reported no differences in ADG, FI or F:G at 4 or 10 weeks into the study. Folman and Eyal (1978) also found no differences in ADG or F:G in Assaf ram lambs fed SBM or FM as sources of supplemental CP.

In contrast, Adam et al. (1982) found that ADG and F:G of lambs of Dorset, Morlam and Finn × Dorset breeding was improved by inclusion of FM into diets with either SBM or cottonseed meal (CSM) as the primary source of supplemental protein. These authors fed titrated amounts of FM to lambs and reported that the optimum amount of FM inclusion was at 2% of the diet. Calhoun et al. (1990) fed lambs (average weight = 48.4 pounds) SBM, CSM, SBM + 3% FM or CSM + 3% FM as supplemental protein in an 84-day growing and finishing trial. These researchers reported that lambs tended to have increased ADG and improved F:G for the 84-day period when FM was included in the diet. They reported a significant improvement in F:G for lambs fed FM for the first 28 days of the trial. Umberger et al. (1988) reported that crossbred lambs fed diets containing SBM and 3% FM had improved F:G compared to lambs fed SBM in one trial, whereas F:G was not affected in a second trial.

Hussein and Jordan (1991b) suggested that less physiologically mature lambs which have a greater metabolizable protein requirement may respond more readily to the level and/or source of dietary protein than more mature lambs. In our study, there was no significant interaction between treatment and week of the experiment for ADG, FI or F:G. Thus, lamb performance was not affected by protein source or level at any point in the finishing period. These data suggest that all diets provided adequate metabolizable protein for growth throughout the finishing period, even with lambs performing well above an industry average for ADG and F:G.

Table 2. Effect of dietary protein level on gain and performance of finishing lambs.

	Crude protein[a]		
Item	13%	16%	SEM[b]
Weight, pounds:			
Initial	76.4	76.5	1.2
Final	117.6	117.2	1.5
ADG, pounds	0.98	0.97	0.08
Feed intake, pound/DM	4.5	4.5	0.14
F:G	4.6	4.63	0.18

[a] Percent of dry matter (DM).
[b] SEM = standard error of the mean.

Table 3. Effect of dietary protein source on gain and performance of finishing lambs.

	Protein source		
Item	SBM	SBM + FM	SEM[a]
Weight, pounds:			
Initial	76.3	76	1.2
Final	117.5	116.7	1.5
ADG, pounds	0.98	0.97	0.08
Feed intake, pound/DM	4.59	4.41	0.14
F:G	4.68	4.55	0.18

[a] SEM = standard error of the mean.

Table 4. Effect of crude protein source on carcass traits.

	Protein source		
Item	SBM	SBM + FM	SEM[a]
Total lean, pounds	34.0	33.7	0.4
Percent lean	54.0	53.6	0.6
Leg lean, pounds	14.9	14.8	0.1
Yield grade	2.08	1.98	0.15
Ribeye area, in^2	2.66	2.68	0.05

[a] SEM = standard error of the mean.

Carcass Traits

The carcass response variables of total lean, percent lean, leg lean and REA were covariant-adjusted to a constant warm carcass weight. Adjusting these variables to a constant warm carcass weight reduced standard error of means by 25% to 50%.

Lambs receiving diets containing SBM or SBM + FM did not differ in the amount of total carcass lean, percentage carcass lean or total leg lean (Table 4). Carcass YG, which is solely determined by a single measurement of fat depth over the center of the ribeye, did not differ due to source of supplemental protein and averaged 2.0. Carcass REA was similar for lambs fed SBM or SBM + FM and averaged 2.7 square inches.

The lack of an effect of FM supplementation on carcass composition is in contrast to the findings of Beerman et al. (1986). These researchers indicated that FM supplementation increased warm carcass weight, dressing percent, REA and leg conformation scores. Additionally they found a 12% increase in REA and an 8% to 10% increase in the weight of the leg, rack and shoulder for Dorset and Dorset × Suffolk lambs fed FM compared with SBM in diets based on corn and grass hay. In that study, lambs weighed 37 to 48 pounds when the study was initiated. Hence, their need for metabolizable protein was likely greater than was the need in our study.

The results of other researchers (Folman and Eyal, 1978; Calhoun et al., 1990) agree with our findings that FM supplementation did not influence lamb carcass composition. Petit and Castonguay (1994) reported that adding FM to grass silage diets increased lamb (Romanov × Finnsheep; Romanov × Suffolk) carcass muscling compared with unsupplemented grass silage diets, but FM had no effect in diets containing silage with supplemental concentrate.

Table 5 contains the effect of CP level on lamb carcass composition. Carcasses from lambs fed 16% CP diets tended to have a higher total lean ($P = 0.14$), higher percentage lean ($P = 0.07$), and more desirable YG ($P = 0.19$) than carcasses from lambs fed 13% CP diets. Leg lean and REA were similar for carcasses regardless of level of dietary CP. Orskov et al. (1971) fed crossbred lambs to appetite diets containing 11%, 15.7% and 19.4% CP. They found that as CP content of the diet increased, there was an increase in nitrogen content and a decrease in fat content of the empty whole body and carcass.

Conclusions

Feeding SBM + FM as supplemental protein to lambs did not result in differences in lamb growth or carcass composition compared with feeding SBM alone. Lamb ADG, FI and F:G were similar regardless of protein source and level. Total carcass lean, percentage carcass lean, leg lean, YG and REA were not influenced by source of dietary protein consumed by lambs. Lambs fed 16% crude protein diets did tend to have carcasses with more total lean, a higher percentage lean and a more desirable YG. Because there were no differences in lamb performance in our study, our recommendations are to use feed cost per unit of gain when deciding on the source and level of CP for finishing lamb diets. Generally, oil seed-based protein sources are more economical than fishmeal and diets containing 13% CP are more economical than those containing 16% CP.

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Table 5. Effect of level of dietary protein on carcass traits.

Item	Crude protein		SEM[a]
	13% of DM	16% of DM	
Total lean, pounds	33.4	34.3	0.4
Percent lean	53.0	54.7	0.6
Leg lean, pounds	14.8	14.9	0.1
Yield grade	2.20	1.86	0.17
Ribeye area, in^2	2.63	2.72	0.05

[a] SEM = standard error of the mean.

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Standard Deviation of Fiber Diameter and Other Characteristics of United States Wool[1,2,3]

C.J. Lupton[4]

Summary

A study was conducted to quantify variability of fiber diameter for a broad cross-section of U.S. wools. Eight hundred sale lots representing eight grades of grease wool were measured for fiber diameter distribution and for wool base, clean wool fibers present and vegetable matter grease basis. No skirts or offsorts were included in the 800 lots which were predominantly staple wools from yearlings and mature ewes representing five different production years. Standard deviation of fiber diameter was below the maximum permitted level (ASTM, 1990; USDA, 1966) for 797 out of 800 lots. Standard deviation of fiber diameter was positively and highly correlated with mean fiber diameter ($r^2 = 0.91$; $P < 0.0001$). No evidence was found to indicate that domestic wools are more variable in terms of fiber diameter than Australian wools.

A discussion of standard deviation of fiber diameter as it affects top making, spinning, yarn properties, fabric properties and selection of sheep for breeding is provided to assist the reader in understanding the significance of these data.

Key words: wool, standard deviation of fiber diameter.

Introduction

Variability in wool fiber diameter is important because it affects spinning condition and the uniformity of yarns into which wool is spun. In turn, uniformity affects yarn strength and the appearance, performance and acceptability of fabric. Compared to several other measurable raw wool characteristics, variability in fiber diameter is considered to be of secondary importance. Table 1 shows an accepted ranking of raw wool properties from the perspective of worsted topmakers. Nevertheless, it should be pointed out that one of the conclusions of the Australian TEAM Project (1985) was that the relative importance of each raw wool characteristic, or group of characteristics, is different for individual mills and is dependent upon the range and type of wools processed. Unfortunately, in that monumental study involving 36,000 bales of wool in 232 commercial consignments, variability of diameter was not immediately available because an air-flow technique was used to measure mean fiber diameter (MFD). Consumers, on the other hand, tend not to be concerned with such things as yield and staple strength, except perhaps for their influence on retail price of the wool product. Rather, they are concerned more with appearance and comfort factors. It has been known for a considerable time that both of these properties are affected by mean fiber diameter and variability of fiber diameter. Because instruments are now available to measure both MFD and wool fiber diameter distribution (standard deviation [SD] and coefficient of variation [CV]) relatively quickly and inexpensively (Baxter et al., 1991; Baird and Barry, 1993), measurement of these two properties is currently attracting considerable industry attention. In November of 1991, CSIRO's Division of Wool Technology organized a workshop to discuss, evaluate and subsequently coordinate research into the effects of fiber diameter variability at all stages of wool production, specification, processing, manufacture and end use. From this meeting, a clearer perception of the use and importance of fiber diameter

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4 Texas Agricultural Experiment Station, Texas A&M University System, 7887 North Highway 87, San Angelo, TX 76901.

measurements emerged (Rottenbury, 1992).

Table 2 shows the official standards of the U.S. for grades of wool (USDA, 1966). It was recognized when these standards were formulated, as it is today, that an excessively high SD would result in a poorer spinning condition and/or a less uniform yarn. Thus commercial raw wool lots having higher SDs than the stated maxima are downgraded by one grade. Because the U.S. textile industry has been aware of this phenomenon, an insistence has been maintained over the years that a measure of variability always accompany the MFD measurement when trading domestic raw wool and tops. Thus as the rest of the world changed to air-flow measurements of MFD for their grease wools, the U.S. stayed with microprojection measurements, even though the latter were tedious and more expensive. For many years now, domestic textile companies have purchased Australian and New Zealand wools based on air-flow measurements and U.S. wool based on microprojection measurements and/or subjective assessments. Over time, a perception has evolved that imported wools are more uniform in terms of fiber diameter than their domestic counterparts.

Table 1. Significance of raw wool characteristics in processing to top.[a]

Characteristic	Importance[b]
Yield	4
Mean fiber diameter	4
Vegetable matter	3
Staple length	3
Staple strength/position of break	3
Color/colored fibers	3
Fiber diameter distribution	2
Staple length variability	2
Degree of cottedness	2
Crimp/resistance to compression	2
Staple tip	1
Age/breed of sheep	1
Style/character/handle	1

[a] Adapted from Andrews (1979) and Quirk (1983).
[b] Scale of importance from 1 to 4, with 4 being the most important and 1 being the least.

For the past several years, the American Sheep Industry Association (ASI) has been conducting a Quality Assurance Program on many aspects of the sheep industry. In the absence of a data base showing fiber diameter variability of U.S. wool over time, ASI sponsored this study with the following objectives: 1) quantify standard deviation of fiber diameter for a broad cross-section of U.S. wool in a recent five-year period; and 2) document data on scoured yield and vegetable matter content for commercial lots of U.S. wool.

Materials and Methods

The following information was supplied by Yocom-McColl Testing Laboratories, Inc., for 800 sale lots of grease wool: wool base (oven-dried scoured wool free of alcohol-extractable matter, mineral matter, vegetable matter and all impurities); clean wool fibers present; vegetable matter grease basis (vegetable matter present); grade; average fiber diameter; standard deviation of fiber diameter; and coefficient of variation of fiber diameter. Fiber diameter (ASTM, 1994b) and yield parameters (ASTM, 1994a) were determined using ASTM methods. Data were summarized for 20 lots in each of eight grades (50s, 54s, 56s, 58s, 60s, 62s, 64s and 70s) for each of five production years (1990-1994). Each lot within a grade was chosen at random from a year's accumulation of lots tested. Thus the reported data represent a random sample of all U.S. sale lots that were tested at this testing lab. These may not be truly representative of all U.S. wool. Because of the nature of the business, most wools were tested in early spring. Descriptions of the wool were also provided and included original bag, skirted and classed, bellies out untied, bellies out tied, etc. No skirts or offsorts were included in the 800 lots, which were predominantly staple wools from yearling and mature ewes representing production from many states. Data were analyzed to provide base-line statistics (mean values, variabilities, minimum and maximum values) for this broad cross-section of U.S. wools. In addition, simple regression and correlation analyses were performed on the data using procedures of SAS (SAS, 1992). Consideration was then given to the role of variation in fiber diameter from the perspectives of: top making; spinning and yarn properties; fabric properties (including the prickle phenomenon); and selection of sheep for breeding.

Table 2. Official standards of the United States for grades of wool (USDA, 1966).

Grade	Range for average fiber diameter, µm	Maximum standard deviation, µm
Finer than 80s	less than 17.70	3.59
80s	17.70 to 19.14	4.09
70s	19.95 to 20.59	4.59
64s	20.60 to 22.04	5.19
62s	23.50 to 24.94	6.49
58s	24.95 to 26.39	7.09
56s	26.40 to 27.84	7.59
54s	27.85 to 29.29	8.19
50s	29.30 to 30.99	8.69
48s	31.00 to 32.69	9.09
46s	32.70 to 34.39	9.59
44s	34.40 to 36.19	10.09
40s	36.20 to 38.09	10.69
36s	38.10 to 40.20	11.19
Coarser than 36s	greater than 40.20	–

Results and Discussion

Standard deviation of fiber diameter and corresponding mean fiber diameter values were plotted for each of the 800 wool samples analyzed by Yocom-McColl Testing Laboratories, Inc. (Figure 1). Of the 800 lots tested, only three had SD of fiber diameter values that exceeded the maxima for grade listed in Table 2.

The linear relationship between SD and MFD for these 800 U.S. sale lots was:

$$SD = 0.36 \times MFD - 3.42$$

for which r^2, the coefficient of determination, was 0.91 ($P < 0.0001$). In other words, 91% of the observed variability in SD is accounted for by the variability in MFD. The same data were summarized by grade (Table 3) and the 95% confidence limits of SD were calculated for the mean SD value in each grade. Thus, for example, the observed mean SD for 60s grade wools was 5.06 µm. If one sample was picked out of the 100 tested, there would be a 95% chance that its SD value was in the range 5.06 ± 0.74 µm corresponding to a range in coefficient of variation (CV%) of 17.8 to 23.9.

The SD data were also summarized by grade and year (Table 4). Although differences between year means for a particular grade do not appear to be sizeable, within-grade differences among SD values due to year were significant ($P < 0.05$, Table 5). Similarly and as expected, grade and location also influenced SD.

Wool base (WB) data were summarized by grade (Table 6) and by grade and year (Table 7). Figure 2 illustrates the relationship between WB and average fiber diameter. Wool base is also affected significantly by year, location and grade ($P < 0.0001$; Table 5). The linear relationship between wool base and mean fiber diameter is:

$$WB = 0.26 \times MFD + 39.88$$

for which $r^2 = 0.05$. The fact that little of the variability in WB is accounted for by MFD is also obvious from Figure 3. Generally, finer wools are considered to be lower yielding than coarser wools. This is not apparent in this data set.

Vegetable matter grease basis (VMGB) data were summarized by grade (Table 8) and by grade and year (Table 9). Figure 3 illustrates the relationship between VMGB and MFD. The VMGB is also affected significantly by year, location and grade ($P < 0.02$; Table 5). The linear relationship between VMGB and MFD is:

$$VMGB = 0.02 \times MFD + 0.85$$

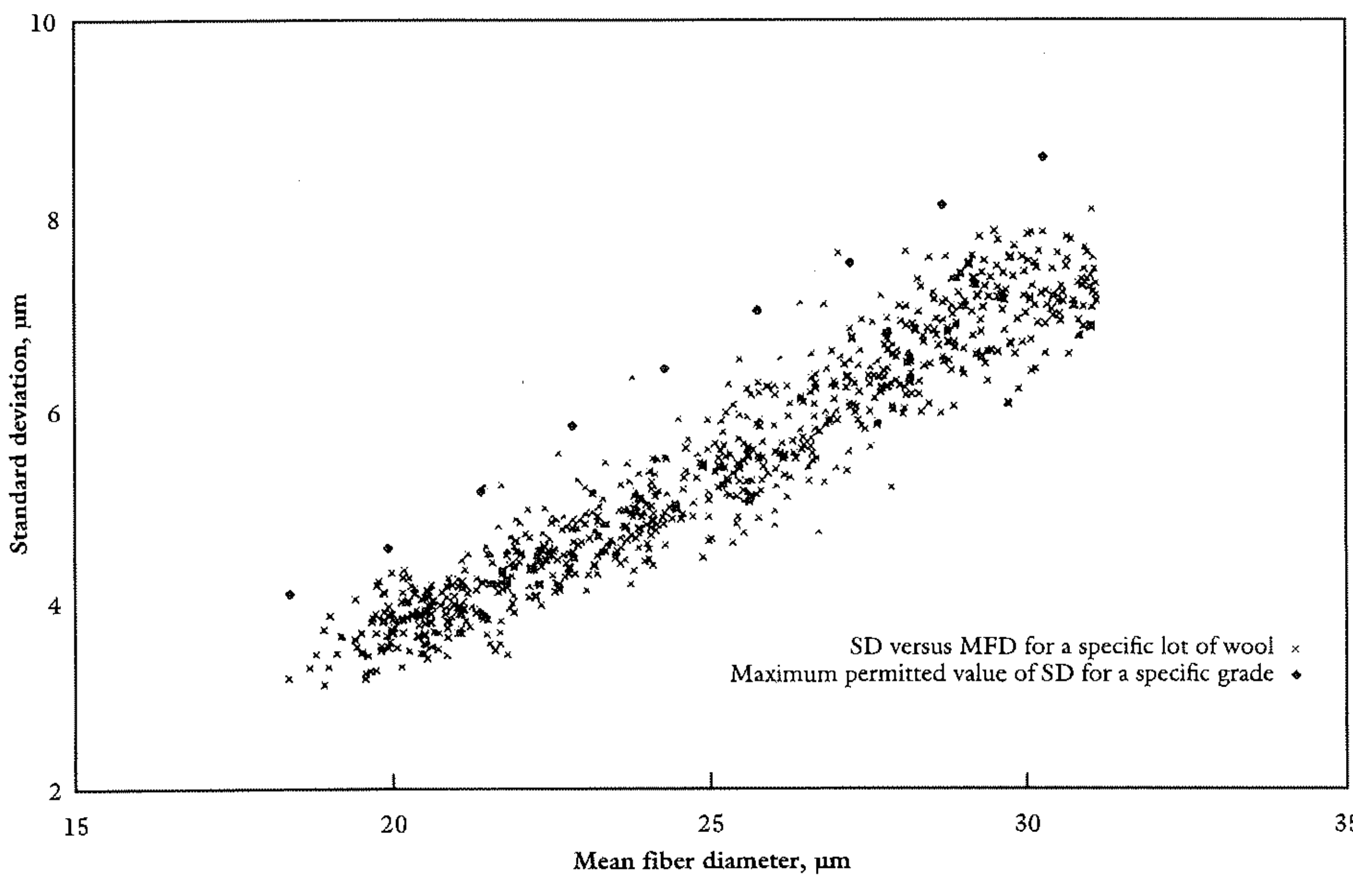
for which $r^2 = 0.01$. It is obvious from Figure 4 that VMGB can not be accurately predicted from a knowledge of MFD.

Correlation coefficients (r-values) and probability values between the wool variables considered in this study are summarized in Table 10. The two highest correlations are between MFD and SD of fiber diameter (0.95) and between WB and clean wool fibers present (CWFP; 0.99).

Variation of wool fiber diameter in a particular population may be expressed as the standard deviation (SD) or coefficient of variation (CV) of fiber diameter:

$$CV\% = \frac{SD}{MFD} \times 100$$

Figure 1. Standard deviation (SD) versus mean fiber diameter (MFD).



The CV tends to provide a more useful statistic for comparing fiber diameter variance of wools differing in MFD since it accounts for the increase in SD with increasing MFD. However, both terms are used in the ensuing discussion.

Instrument Considerations

The shortcomings of airflow instruments for measuring MFD of wool are well known (James and David, 1968). Baxter (1993) recently summarized the numerous conditions that cause airflow instruments to produce incorrect results. These included fiber medullation (which affects specific gravity), atypical crimp, ellipticity, unusual scale geometry, substantially different CVs between calibration and measurement wools, high residual grease level, other contaminants and non-standard preparation methods. Edmunds (1993) also documented the effects of standard deviation on airflow measurements of MFD for 228 New Zealand wools and concluded that uncertainty arises as to the accuracy of MFD measurements whenever SD is unknown. For these and other reasons, scientists have invented and subsequently proven instruments that will ultimately replace even the commercial use of airflow while producing results more rapidly but still as accurately as the projection microscope (PM). Two such instruments are the Sirolan Laserscan (Baird and Barry, 1993) and the Optical Fibre Diameter Analyser (OFDA; Baxter et al., 1991). Even with these high-tech instruments, some potential problems remain. Naylor (1992) observed that precision of measurement of the "coarse edge" of fiber diameter distribution is sensitive to instrument calibration. However, precision increased as number of fibers measured increased. In earlier versions of the Laserscan (e.g., the fiber fineness distribution analyser [FFDA]), De Oliveira et al. (1990) reported that medullation and wools with high CVs produced finer MFDs on the FFDA versus the PM. This problem has reportedly been overcome in the Laserscan. More recently, Teasdale (1993) described the bias in CV of fiber diameter caused by using the average diameter of fiber snippets in the Laserscan versus projection microscope and OFDA measurements in which measurements at a point on the snippet are used. Theoretically, FFDA and Laserscan would produce lower CVs of fiber diameter than the PM and the OFDA. The effect is small, in the order of 0.5% of CV. For the current study, projection microscope measurements (ASTM, 1993) were used throughout.

Raw Wool Considerations

Only limited information is available concerning variability of fiber diameter in greasy wool sale lots. It is known, however, that the major source of variation exists within single staples rather than within the fleece or among fleeces within a lot (Dunlop and McMahon, 1974; Stobart et al., 1986). Whiteley et al. (1984) presented mean values observed for the SD of diameter of 2,921 sale lots of common Merino and crossbred fleece wools and skirtings (ranging in MFD from 18.5 to 36.6 µm). For all types of wool considered, SD increased with MFD. The relationships between SD and MFD were linear (but different) for each of the four types of wool considered. For the pooled results, the derived equation was:

$$SD = 0.263 \times MFD - 0.325$$

having a correlation coefficient, r = 0.903. The 95% confidence intervals for the SD of fiber diameter of an individual sale lot about the mean value for a given MFD value was ±1.0 µm. The regression equation derived in the present study for 800 sale lots of U.S. origin is somewhat different than that presented by Whiteley et al. (1984). First, the coefficient of determination of the equation for U.S. wools was higher (0.91 vs. 0.82) and the 95% confidence limits were lower (±0.72 µm vs. ±1.00 µm). One explanation for this difference was thought to be that the Australian data set included fleece wools and skirts whereas the U.S. data were from skirted and original bag wools with no lots containing skirts only. A particularly interesting aspect of the Australian work was that no difference in SD between fleece wools and skirts could be demonstrated. In fact, other research (Thompson et al., 1983) showed that variations in SD produced by different forms of clip preparation (on-farm classing, interlotting, bulk classing) are very small. The first obvious inference is that improvement (reduction) in SD cannot be achieved with skirting alone and a genetic approach must also be attempted. A second possible explanation for the different regression equations is that different instruments were used to quantify MFD and SD. In Australia, the FFDA was used while in the U.S., microprojection was the

Table 3. Standard deviation of average fiber diameter and its 95% confidence limits by grade.

Grade	Mid-point of grade, µm	Number of lots	Mean SD, µm	SD of SD, µm	Corresponding CV, %	Confidence limits 95% of SD, ± µm	Minimum SD, µm	Maximum SD, µm
50	30.15	100	7.25	0.40	24.05	0.78	6.15	8.15
54	28.57	100	6.89	0.44	24.12	0.86	6.04	7.86
56	27.12	100	6.27	0.48	23.12	0.94	4.81	7.69
58	25.67	100	5.60	0.42	21.82	0.82	4.68	6.62
60	24.22	100	5.06	0.38	20.89	0.74	4.23	6.40
62	22.77	100	4.62	0.32	20.29	0.63	4.00	5.61
64	21.32	100	4.13	0.36	19.37	0.71	3.44	5.26
70	19.87	91	3.81	0.27	19.17	0.53	3.18	4.35
80	18.42	9	3.44	0.25	18.68	0.49	3.11	3.86

measurement of choice. The FFDA is known to produce higher SD values than the microprojector while producing similar values for MFD, particularly when measuring mini-cored scoured wool (Qi et al., 1994). A third explanation for the different equations is that U.S. wools are more uniform in terms of fiber diameter than Australian wools. Using the Australian equation, a 20-µm Australian wool would be expected to have a SD of fiber diameter equal to 4.94 µm. This is actually higher than the maximum value of 4.59 µm permitted in the U.S. grading system. This compares to 3.78 µm for a 20-µm U.S. sale lot, obtained using the equation derived in this study.

A more recent study (Crook et al., 1994) conducted in conjunction with the Peppin Merino stud industry of New South Wales, Australia, produced measurements that tend to support the third explanation mentioned above. In addition, estimates of phenotypic correlations were calculated that indicated that standard deviation of fiber diameter is significantly ($P < 0.05$) and positively associated with traits such as handle, crimp definition, staple thickness and staple formation. Ewes displaying staple characteristics generally regarded as desirable by stud breeders tended to have lower SDs of fiber diameter. The authors advocated caution in using this phenotypic information until the genetic associations had been established. In this study, wool and fleece characteristics were examined on 100 unclassed hogget ewes in each of seven studs. Wool samples were removed from the midside region, minicored and measured for MFD and SD using the Sirolan-Laserscan (5,000 x 2 mm snippets per sample). The phenotypic correlation within a stud between MFD and SD ranged from 0.33 to 0.48. Overall, MFD was 20.10 µm with an average SD of 4.33 µm for these 700 side-samples. Using the regression equation derived for U.S. wool sale lots, a SD of fiber diameter of 3.82 µm would be estimated for 20.10-µm wool. Since midside samples would normally be more uniform in fiber diameter than commercial sale lots (of the same MFD) and since the Laserscan is known to produce SD values very similar to those resulting from projection microscope measurements (Stobart, 1994), it may be concluded that the U.S. sale lots measured in this study tend to have lower SDs of fiber diameter than the ewes in this particular Australian study.

Whiteley and Thompson (1985) estimated "coarse edge" in 2,192 greasy wool sale lots by recording the percentage of fibers greater than 1.5 times the MFD. However, they concluded that because of the close multiple correlation between this statistic and MFD and SD, any effects of coarse edge on fabric properties could be adequately predicted by these second order (MFD and SD) statistics. This was considered to be advantageous because MFD and SD can be measured more precisely than coarse edge statistics even with modern instruments. Work described in the next section (e.g., Garnsworthy et al., 1988a and b concerning fabric

Table 4. Mean values of standard deviation of fiber diameter by year and grade.

Grade	Number of lots/year	Year 1990	1991	1992	1993	1994
50	20	7.04	7.43	7.22	7.29	7.26
54	20	6.89	6.99	6.78	6.86	6.92
56	20	6.11	6.32	6.47	6.20	6.25
58	20	5.40	5.56	5.63	5.71	5.71
60	20	5.01	5.01	5.12	5.15	5.02
62	20	4.55	4.60	4.55	4.68	4.70
64	20	4.18	3.97	4.09	4.20	4.21
70	(15, 20, 17, 20, 19)[a]	5.85	3.83	3.75	3.80	3.81
80	(5, 0, 3, 0, 1)[a]	3.52	–	3.36	–	–

[a] The number of lots was not equal among years.

Table 5. Effects of year, location and grade on standard deviation of fiber diameter and other wool characteristics (P-values).

	SD[a]	AFD[b]	WB[c]	VMGB[d]
Year	0.0237	0.0064	0.0001	0.0019
Location	< 0.0001	< 0.0001	0.0001	0.0001
Grade	0.0001	< 0.0001	0.0001	0.0125

[a] SD = standard deviation.
[b] AFD = average fiber diameter.
[c] WB = wool base.
[d] VWGB = vegetable matter grease basis.

Table 6. Mean values of wool base by grade.

Grade	Number of lots	Mean wool base, %	Minimum wool base, %	Maximum wool base, %	SD of wool base, %
50	100	47.74	41.6	53.6	2.44
54	100	47.29	42.3	55.4	2.45
56	100	47.10	37.1	55.6	2.97
58	100	46.79	37.8	56.1	3.68
60	100	45.84	35.5	53.0	3.65
62	100	44.66	29.4	53.5	3.87
64	100	44.96	34.9	55.3	4.12
70	91	46.02	29.7	55.2	5.06
80	9	46.84	38.6	54.4	4.66

prickle) appears to contradict this conclusion.

Processing and Fabric Considerations

From a theoretical viewpoint, Martindale (1945; 1969) concluded years ago that there is a real (but small) effect of variability of fiber diameter on yarn evenness. From Martindale's equation for ideal yarn evenness, it can be derived (De Groot, 1992) that:

$$CV\%_{yarn} = 3.208D\sqrt{\frac{1+5\left(\frac{V}{100}\right)^2}{T}}$$

in which: $CV\%_{yarn}$ = coefficient of variation of yarn cross sectional area; T = yarn linear density in tex; D = mean fiber diameter; and V = CV% of fiber diameter.

This relationship was supported by the work of Lang and Rankin (1968) and Corbett et al. (1968) who showed small increases in yarn evenness, strength and extension at break with decreasing CV of fiber diameter. Turpie's work (1977) also provided evidence that the level of variability in fiber diameter of wool top influences spinning performance. However, expected improvement in fabric handle with decreasing CV was not always apparent (e.g., Hunter, 1976).

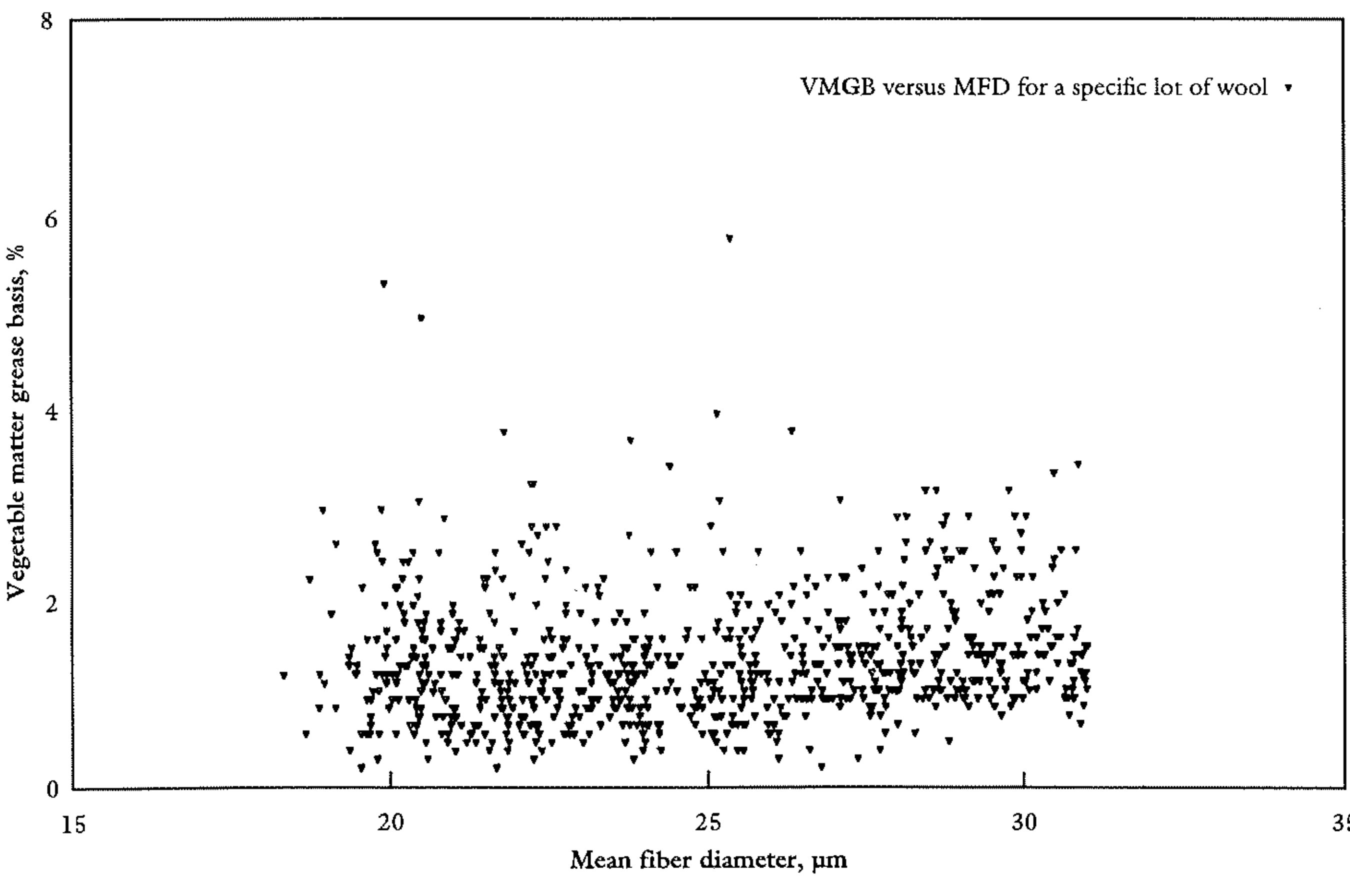
Bow and David (1992) noted the most comprehensive collection of data concerning standard deviation of fiber diameter is due to Ott (1958) who derived a relationship between SD and MFD based on measurements of 5,855 tops. In their study, Bow and David derived two linear regression equations for two different popula-

Table 7. Mean values of wool base by year and grade.

Grade	Number of lots/year	Year 1990	1991	1992	1993	1994
50	20	46.91	47.87	47.48	47.44	49.01
54	20	46.31	47.17	47.23	47.92	47.80
56	20	46.92	45.32	46.30	48.69	48.24
58	20	45.42	44.98	46.83	48.41	48.32
60	20	44.94	44.47	45.14	47.19	47.46
62	20	42.59	44.38	44.43	46.37	45.52
64	20	43.15	43.78	45.80	47.05	45.03
70	(15, 20, 17, 20, 19)[a]	41.31	45.82	49.44	47.02	45.83
80	(5, 0, 3, 0, 1)[a]	44.80	–	50.60	–	–

[a] The number of lots was not equal among years.

Figure 2. Vegetable matter grease basis (VMGB) versus mean fiber diameter (MFD).

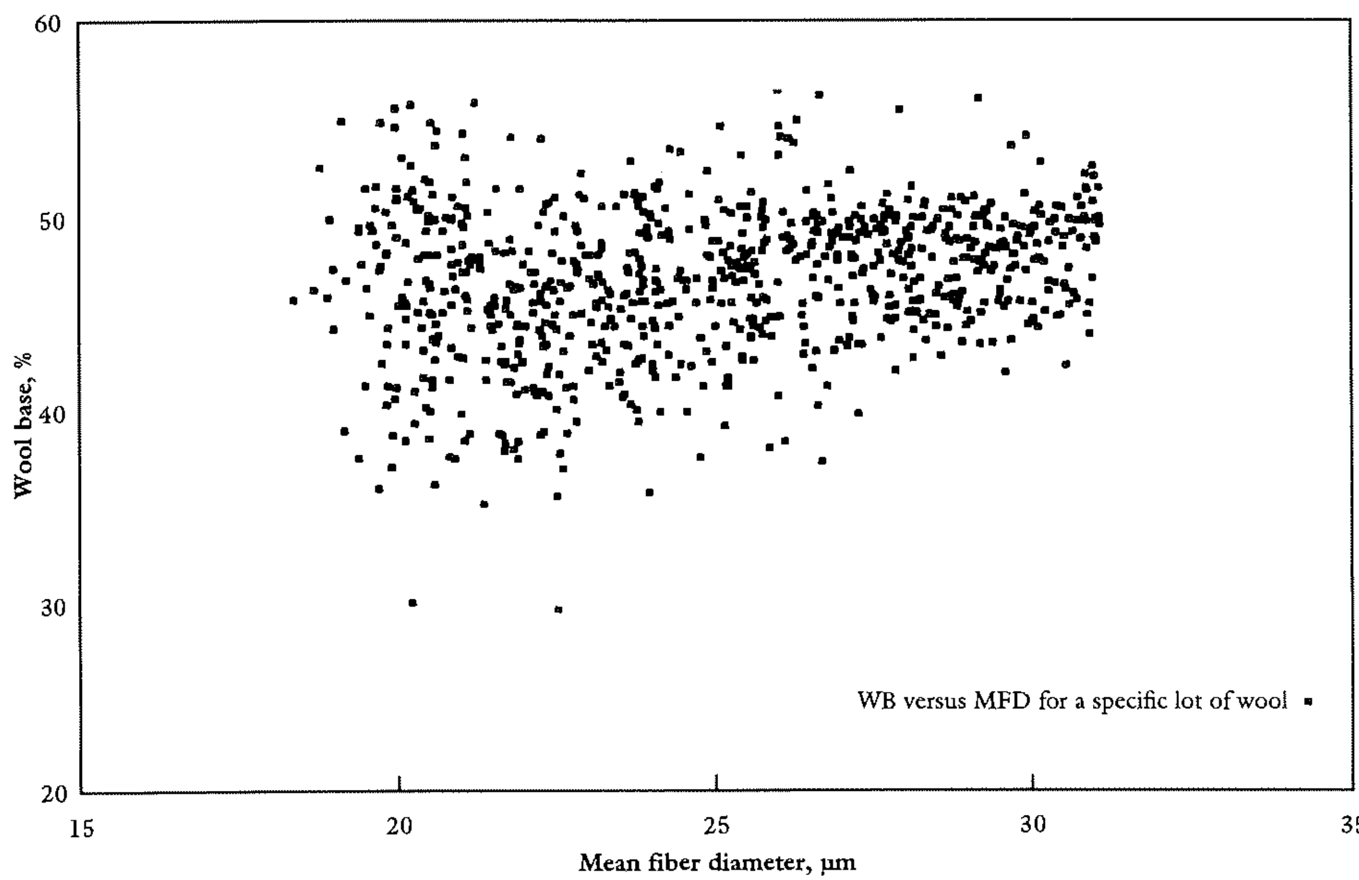


tions of Australian wools. The first data set included 222 of the TEAM tops (large consignments processed commercially) while the second consisted of 162 sale display samples (processed at mini-scale plant). Measurements were made using the FFDA instrument (Lynch and Michie, 1976) on tops in the MFD range of 17 to 32 µm. Because the regression equations for the two data sets were different (and also different from a previously derived equation [Lunney, 1983]), Bow and David concluded there may not be a universal linear relationship for SD and MFD in wool tops. The authors did note that within this diameter range, CV of fiber diameter was relatively constant at 24%. Hunter (1980) pointed out that distribution of fiber diameter in raw wool closely resembles that in tops made from it despite the removal of noils and would therefore be worthy of consideration in a value-based marketing system. He also observed that CV of fiber diameter is important in processing because *(inter alia)* abnormal amounts of fine fibers in a blend result in excessive nep formation. Generally, as CV of fiber diameter increases, spinning performance decreases. However, compared to MFD, Hunter also concluded the effects of CV of fiber diameter are small. The effect on spinning limit of an increase of 1% in CV of fiber diameter is equivalent to an increase of 0.4% in MFD (Roberts, 1961). More recently, Lamb (1992) theorized that CV of fiber diameter is only about one-fifth as important as MFD. Thus a reduction in CV from 25% to 20% is equivalent to replacing a 21-µm with a 20-µm wool in terms of yarn evenness, strength and spinning performance. Such considerations increase in importance when textile mills attempt to spin the finest yarns possible at the fastest speeds possible from a specific production lot (invariably a mixture of sale lots).

Hunter (1980) recognized, as many researchers have since, that an excessively high proportion of coarse fibers in an apparel wool blend would give rise to prickliness in the resulting fabric. Garnsworthy et al. (1988a,b) noted that fabric-evoked prickle in a knitted fabric is proportional to the number of fibers coarser than 30 µm, 5% being a critical cut-off point for most individuals. Kenins (1992) concluded prickle is not an allergic reaction to wool but a sensation caused by coarse fibers indenting the skin and activating pain nerve fibers. These conclusions were confirmed by Naylor (1992a), who produced similar reactions on human subjects using fabrics composed wholly of acrylic fibers.

De Groot (1992) evaluated fabrics composed of 23-µm wool having CVs ranging from 21 to 27%. He concluded that fabric bending rigidity, smoothness and perceived prickle were all related to CV of fiber diam-

Figure 3. Wool base (WB) versus mean fiber diameter (MFD).



eter. However, in his limited trial he was not able to demonstrate a relationship between CV of fiber diameter and yarn evenness or tensile properties. Participants in De Groot's subjective fabric evaluation were able to distinguish between fabrics containing 21 and 27% CV wools but not between 21 and 24% or 24 and 27%. Naylor (1992b) pointed out that the relationship between fiber diameter distributions in wool top and yarn surface fibers is actually more complex than it may first appear. In the top structure, fiber ends tend to be finer than in the bulk of the top. During spinning, coarser fibers tend to migrate to the yarn surface where relatively coarse fiber ends result in prickle.

To this point, the discussion has been concerned primarily with the effects of fiber diameter variability on apparel-type products made with apparel wools. Ross et al. (1987) studied the effects of MFD and CV in the manufacture of woolen and semi-worsted carpets from Romcross wools (MFD = 30 to 40 µm) and concluded that neither MFD nor variability of fiber diameter played a major role in either processing or product performance.

Table 8. Mean values of vegetable matter grease basis (VMGB) by grade.

Grade	Number of lots	Mean VMBG, %	Minimum VMBG, %	Maximum VMBG, %	SD of VMBG, %
50	100	1.67	0.7	3.7	0.65
54	100	1.67	0.5	3.4	0.68
56	100	1.42	0.2	3.3	0.54
58	100	1.38	0.3	6.3	0.88
60	100	1.31	0.3	4.0	0.64
62	100	1.37	0.3	3.5	0.71
64	100	1.28	0.2	4.1	0.66
70	91	1.56	0.2	5.8	0.92
80	9	1.53	0.6	3.2	0.84

Table 9. Mean values of vegetable matter grease basis (VMGB) by year and grade.

Grade	Number of lots/year	Year				
		1990	1991	1992	1993	1994
50	20	1.91	1.76	1.55	1.74	1.42
54	20	2.00	1.80	1.41	1.44	1.73
56	20	1.39	1.48	1.55	1.24	1.46
58	20	1.71	1.46	1.32	1.31	1.11
60	20	1.56	1.31	1.27	1.19	1.25
62	20	1.52	1.20	1.30	1.43	1.42
64	20	1.17	1.32	1.37	1.27	1.25
70	(15, 20, 17, 20, 19)[a]	1.88	1.70	1.80	1.33	1.18
80	(5, 0, 3, 0, 1)[a]	1.50	–	1.90	–	–

[a] The number of lots was not equal among years.

Table 10. Correlation coefficients between selected characteristics of U.S. wool (r-values and probabilities).

	MFD[a]	WB[b]	CWFP[c]	VMGB[d]
SD[e]	0.95 (< 0.0001)	0.18 (0.0001)	0.18 (0.0001)	0.17 (0.0001)
MFD[a]	–	0.23 (0.0001)	0.23 (0.0001)	0.11 (0.0014)
WB[b]	–	–	0.99 (< 0.0001)	–0.21 (0.0001)
CWFP[c]	–	–	–	–0.21 (0.0001)

[a] MFD = average fiber diameter.
[b] WB = wool base.
[c] CWFP = clean wool fibers present.
[d] VWGB = vegetable matter grease basis.
[e] SD = standard deviation.

Sheep Breeding and Management Considerations

Hansford (1992) presented a wool "quality equation" (Figure 4) showing how wool growers can use breeding and management to affect fleece quality and then use clip preparation practices to impact on the raw product or clip quality. She emphasized that producers should persevere with raw wool specification in order to supply a more desirable raw material to their customers in the textile industry. Shearing interval, the timing of shearing particularly in relation to lambing and a satisfactory supplemental feeding program are other major factors that can impact wool quality. Dunlop and McMahon (1974) estimated variation in fiber diameter in five Merino strains in the following categories: among sheep (11 to 24%); among sites over the body of the sheep (6 to 12%); among fibers within sites (61 to 80%); and among points along the fiber (3 to 6%). Stobart et al. (1986) conducted a similar study in which fiber diameter variability of fleeces from U.S. Rambouillet, Columbia, Hampshire and western white-faced (Rambouillet-Columbia cross) commercial ewes was quantified. The components of variance in fiber diameter within a lot of wool due to different sources in the case of purebred fleeces were: among fleeces (9 to 13%); among body regions (5 to 14%); among fibers (67 to 82%); and among points along the fiber (3 to 6%). These results were very similar to the earlier findings of Dunlop and McMahon (1974) and also Quinnel et al. (1973). However, Stobart et al. noted substantially higher (25 to 57%) among-fleece variation for crossbred sheep. All these studies suggest that only limited reductions in variability of fiber diameter might be expected by closer control of the sheep's environment, greater attention to uniformity among fleeces and better skirting and classing. Theoretically, SD of fiber diameter might be reduced over time by selecting sheep having low among-fiber variation in fiber diameter. This assumes such sheep exist and heritability of this trait is at least moderately high. Piper and Lax (1992) reported the heritability of SD of fiber diameter to be 0.49. According to a recent study by Gifford et al. (1994) with South Australian Merino sheep, heritability of CV of fiber diameter ranges from 0.57 to 0.73 (0.51 to 0.67 for SD of fiber diameter). Both these estimates are substantially higher than that (0.14) due to Shelton and Lewis (1986) for side-britch MFD difference but similar in magnitude to the heritability of this latter trait (0.5) calculated by Jones (1986). James and Ponzoni (1992) had earlier concluded that fiber diameter variability would respond rapidly in selection of South Australian Merinos. These authors also predicted that selection for reduced SD of fiber diameter would lead to a concurrent reduction in MFD and fleece weight. In contrast, selection for reduced CV of fiber diameter would have little or no effect on these other characteristics. Ponzoni and Brien (1993) indicated that a measure of fiber diameter variability would be incorporated into WOOLPLAN (the Australian national performance recording scheme for wool sheep breeders) in the near future, despite the paucity of information concerning phenotypic and genetic parameters and economic significance of the variability in fiber diameter measurements. Only six years ago, Rogan (1988) argued that fiber diameter variability should receive no attention as a sheep breeding objective until such time as the wool processing industry established clear price differentials. At such time, progress in reducing fiber diameter variability genetically could be achieved rapidly due to the relatively high (0.46, Rogan's estimate) heritability of within-fleece fiber diameter variability. In the meantime, selection for reduced fiber diameter by apparel wool growers would likely result in reduced fiber diameter variability. Delport and Botha (1994) reached a similar conclusion in their consideration of reducing fiber diameter and coarse edge in South African Dohne Merinos. The value of including fiber diameter variability in breeding objectives and selection criteria for Merino sheep was also studied by Piper and Lax (1992) in the context of various WOOLPLAN options. They concluded that options which result in MFD reduction would concurrently reduce SD of fiber diameter but could result in a marginal increase in CV of fiber diameter. To date, there are still no clear price signals from the wool market that would enable estimation of a relative economic weight for fiber diameter variability in a selection index. Consequently, these authors predicted the effect on gain in economic merit ($ per ewe lifetime) of including CV of fiber diameter in the selection index would be negligible.

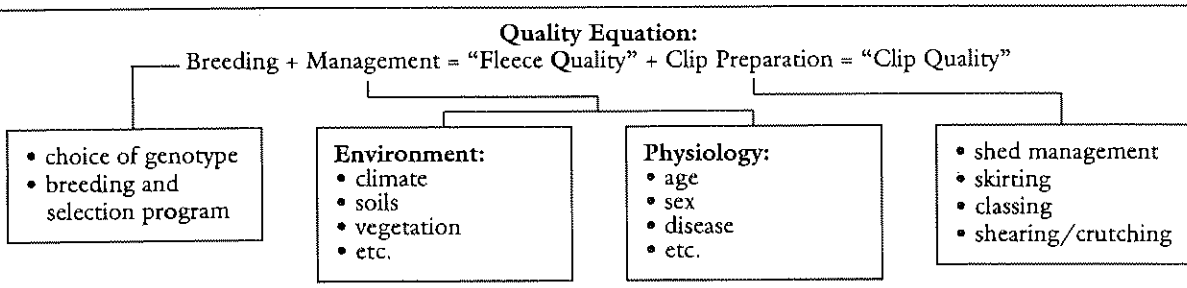
For yearling Rambouillet rams in two central performance tests, the CV of fiber diameter of whole fleeces is only poorly correlated (r = 0.15) with the difference in MFD between side and britch samples (Iman et al., 1990). These authors pointed out that even though CV provides the best estimate of fiber diameter variability for the whole fleece, it is not a good indicator of coarse edge. A major implication for ram testing and subsequent selection of stud rams is that CV is not a sensitive indicator of coarse britch wool. This objectionable trait is best examined by direct measurement or at least estimated from a histogram of the whole fleece. The former course of action, particularly when considering an animal for stud purposes, has long been advocated by Jones (1986) who concluded that the two traits "difference between side and britch MFD" and "fleece uniformity" (as indicated by CV or SD, respectively) are controlled by two different genes and thus must be selected separately.

With modern instrumentation and the availability of relatively inexpensive ($5 per sample) tests for fiber diameter distribution, the U.S. breeder now has access to a full histogram in addition to the basic fiber diameter statistics (mean, SD, CV). If samples representative of individual skirted fleeces are submitted for testing, the histogram may be used to calculate both coarse edge and potential prickle in fabrics. The former term is more general and potentially more applicable and useful to all breeds and grades of wool, though to date its use has been limited primarily to finewool breeds. The term "prickle" is more absolute, being an indication of whether fabric prickle will occur or not when a wool fabric composed of the wool being tested is worn next to the skin. Prickle, coarse edge and SD (or CV) might all be considered as selection criteria by breeders of finewool sheep.

Conclusions

This study has provided a data base containing SD of fiber diameter, yield and vegetable matter content from which progress can be assessed in future years. In addition, these data

Figure 4. Hansford's wool quality equation.



will permit an individual producer to compare the traits in his clip with the sale lots tested. The SD of fiber diameter of commercial sale lots is invariably below the maximum level permitted in the U.S. grading system. Nevertheless, further improvement in this trait is possible through selective breeding and continued attention to recommended management and clip preparation practices. Because of the continued efforts of breeders, county agents, warehousemen and many other concerned wool people and their industry associations, no evidence was found to indicate that domestic wools are more variable in terms of fiber diameter than Australian wools.

A discussion of SD of fiber diameter as it affects top making, spinning, yarn properties, fabric properties and selection of sheep for breeding was provided to assist the reader in understanding the significance of the data.

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Sheep Production Response to Continuous and Rotational Stocking on Dryland Alfalfa/Grass Pasture

V.M. Thomas[1,2,3], R.W. Kott[1] and R.W. Ditterline[1]

Summary

Grazing alfalfa *(Medicago sativa L.)* during spring and summer could provide excellent forage for sheep with high nutritional requirements such as lactating ewes and suckling lambs. This study evaluated the influence of two grazing management systems on the productivity of sheep grazing a mixed stand of dryland alfalfa and orchardgrass *(Dactylis glomerata L.)*. The two grazing treatments were: 1) continuous stocking (CS); and 2) rotational stocking (RS). The grazing studies began on May 19, 1992, and May 21, 1993.

Stocking rates were 3.1 ewes and 5.5 lambs per acre in 1992. Ewe daily gain was higher ($P < 0.01$) and lamb daily gain was lower ($P < 0.05$) for RS compared to CS. Ewe and lamb gains per acre were similar ($P > 0.10$) between treatments due to lower ewe and higher lamb grazing days on the RS paddocks. Stocking rates were 3.6 ewes and 6.5 lambs per acre in 1993. Ewe daily gain and gain per acre were greater ($P < 0.01$) for RS; however, lamb daily gain and gain per acre were unaffected ($P > 0.10$) by grazing treatments. Grazing dryland alfalfa and orchardgrass paddocks during the spring and summer in Montana with ewes and lambs resulted in lamb gains of 0.55 and 0.65 pounds per day or 268 and 319 pounds per acre for 1992 and 1993, respectively. Grazing system did not influence pounds of lamb produced per acre when similar stocking rates were used in both grazing systems.

Key words: sheep, grazing system, alfalfa, dryland.

Introduction

In the western United States, sheep commonly graze alfalfa during the fall and winter. Spring and summer grazing of alfalfa is avoided because of the potential for bloat. However, if a bloat preventive is fed, or grass is interseeded with the alfalfa, grazing may be accomplished with minimal problems from bloat. Grazing alfalfa during the spring and summer could provide excellent forage for sheep with high nutritional requirements such as lactating ewes and suckling lambs.

Alfalfa stand failures resulting from continuous stocking have been reported (McKinney, 1974; Hill and Saville, 1976). To maintain productivity and stand longevity, long periods of rest between grazing periods are required (Smallfield et al. 1980). Townsend (1990) studied the effect of rotational stocking (RS) on alfalfa yield, stand persistence and nutritional quality in Montana. Results suggested that 50% of the alfalfa topgrowth could be removed if fall grazing was deferred to replenish carbohydrate reserves.

Limited information is available on grazing management of sheep grazing dryland alfalfa under RS in the Intermountain West. The objective of this study was to evaluate sheep production during the summer on dryland alfalfa/orchardgrass pasture using both continuous and rotational stocking.

Materials and Methods

This study was conducted in 1992 and 1993 at the Montana State University Ft. Ellis Agricultural Experiment Station near Bozeman, MT. A mixture of Sure alfalfa *(Medicago sativa L.)* and Latar orchardgrass *(Dactylis glomerata L.)* was seeded in 1990 on a clay-loam soil at 8 and 2 pounds per acre, respectively. Fertilizer was applied immediately following seeding to raise soil fertility to provide 70, 300 and 25 pounds per

[1] Montana State University, Bozeman, MT 59715.

[2] Contribution from Montana Agricultural Experiment Station, Journal series No. J-2941.

[3] Corresponding author: Rodney Kott, Montana State University, Bozeman, MT 59717; phone (406) 994-3415, fax (406) 994-5589.

acre of N, P_2O_5 and S, respectively. No fertilizer was applied after stand establishment.

Crossbred ewes of either 1/4 Finn and 3/4 Targhee or 3/8 Finn and 5/8 Targhee were used for the study. The mean birth dates of the lambs were April 20, 1992, and April 7, 1993. Ewes were blocked by age, lambing date and litter size, and were randomly assigned to treatment. Ewes were dosed with an anthelmintic approximately 21 days before lambing. Ewes were dosed a second time and lambs for the first time on June 3, 1992, and prior to turnout on pasture in May of 1993. All ewes and lambs were dewormed at weaning. Fecal egg counts were determined at weaning in ewes and lambs in 1993.

Two grazing treatments which were replicated twice were: 1) continuous stocking (CS); and 2) rotational stocking (RS). Each RS paddock was 0.5 acres (8 paddocks per replicate) with each replication being approximately 4 acres. The CS paddocks were approximately 4 acres each.

The CS and RS paddocks were stocked in 1992 at 3.1 ± 0.3 ewes and 5.5 ± 0.5 lambs per acre, whereas in 1993 the initial stocking rate was increased to 3.6 ± 0.2 ewes and 6.5 ± 0.1 lambs per acre. The first cycle of grazing began in mid-May in each year (May 19, 1992; May 21, 1993). Grazing cycle among paddocks in the RS system was based on a fixed period spent in each paddock, with ewes and lambs being moved every two days during the first grazing cycle (paddock rest of 14 days), every three days during the second grazing cycle (paddock rest of 21 days) and a minimum of every five days during the third and final grazing cycle (paddock rest of 35 days). Some RS replicates were grazed a fourth time due to an abundance of available forage in this treatment. The progressive increase in length of occupation and rest period corresponded to declining vegetative growth (Voisin, 1962).

The density and composition of the pasture stand was measured using an occupancy meter prior to grazing each year (Townsend, 1990). Counts were taken each spring when the plants were approximately five inches tall. Occupancy in 1992 was 98% for alfalfa plants. Percentage occupancy was not determined for orchardgrass plants because they appeared to represent a low percentage of the total plant population. Percentage occupancy in 1993 RS replicate 1 was 87% for alfalfa and 12% for orchardgrass; RS replicate 2 alfalfa and orchardgrass occupancies were 86% and 9%, respectively. The CS replicates had an alfalfa occupancy of 88% with replicates 1

Table 1. Available forage, crude protein concentrations and neutral detergent fiber of mixed alfalfa and orchardgrass paddock in 1992 and 1993 near Bozeman, MT.[a]

	1992 Grazing System					
	Continuous stocking			Rotation stocking		
Date	Forage available, pound/acre	CP[b], %	NDF[c], %	Forage available, pound/acre	CP[b], %	NDF[c], %
May 19	3,180	26.6	28.3	3,542	24.9	39.9
May 27	3,384	21.1	35.8	3,722	22.7	34.6
June 4	3,604	18.5	38.9	3,637	20.2	34.5
June 16	3,080	14.4	53.0	3,447	16.9	46.9
June 28	2,379	15.5	52.5	3,668	15.8	49.9
July 18	1,684	15.2	55.9	3,353	19.8	44.5
August 13	2,327	9.0	65.6	2,493	14.7	49.4
Average	2805	17.1	47.1	3,408	19.2	42.8
	1993 Grazing System					
	Continuous stocking			Rotation stocking		
Date	Forage available, pound/acre	CP[b], %	NDF[c], %	Forage available, pound/acre	CP[b], %	NDF[c], %
May 20	3,385	23.0	39.6	3,560	24.1	38.4
June 6	4,097	19.6	46.9	4,326	22.3	42.6
June 30	2,730	14.4	57.0	3,770	23.4	42.5
August 13	1,869	22.5	45.1	2,971	21.7	43.0
Average	3,037	19.8	47.1	3,646	22.8	41.6

[a] Samples were collected prior to grazing in rotation stocking paddocks and on the same date in the continuous paddocks.
[b] CP = crude protein.
[c] NDF = neutral detergent fiber.

and 2 having an orchardgrass occupancy of 7% and 12%, respectively.

Orchardgrass plant height in 1993 was approximately 25 inches on July 1. Therefore, on July 2 all pastures were clipped to 12 inches to facilitate orchardgrass utilization by the sheep and prevent shading of the alfalfa plants.

Available forage was sampled before grazing in the first and fifth paddocks in the grazing sequence of both RS replicates and in the CS paddocks at the time of sampling the RS paddocks. Standing forage was hand-clipped from three quadrates (2.7 square feet) to a one-inch stubble height. Samples were analyzed for crude protein (CP) and neutral detergent fiber (NDF) concentrations (Goering and Van Soest, 1970). Estimates of forage availability, CP and NDF content are reported in Table 1.

Ewe and lamb body weights (BW) were determined following a 12-hour shrink period at the beginning and end of the summer grazing period.

Table 2. Weather data for Bozeman, MT, during the 1992 and 1993 growing seasons. Data for the 30-year average are from 1960-1990.

Precipitation, inches			
	Year		
Month	1992	1993	30-year average
April	3.1	3.2	1.8
May	2.8	3.3	2.9
June	5.5	4.2	2.9
July	1.7	5.0	1.3
August	0.9	2.9	1.4
Total	14.0	18.6	10.3

Daily air temperature, °F			
	Year		
Month	1992	1993	30-year average
April	47.5	43.5	42.6
May	56.4	56.3	51.5
June	62.1	57.4	60.0
July	62.4	58.6	67.3
August	64.1	60.7	65.8
Average	58.5	55.3	57.4

Ewes and their lambs were removed from the CS and RS paddocks on August 13 and 21, 1992, and August 13, 1993. These dates were four to six weeks before the first killing frost and were selected to ensure adequate replenishing of carbohydrate reserves and crown bud initiation (Ditterline et al., 1979). Following a killing frost, the RS paddocks were grazed from mid-October to mid-November with sheep in 1992 and cattle and sheep in 1993. The CS paddocks were not grazed in the fall of 1993 because of insufficient forage.

To minimize the risk of bloat, ewes and lambs had ad libitum access to a mineral mixture composed of 50% trace mineralized salt, 30% ground barley *(Hordeum vulgare L.)* and 20% poloxalene, an anti-bloat agent. However, three ewes and lambs died from bloat in 1992 and two ewes died in 1993. Also, coyote predation was responsible for the death of 10 lambs at the beginning of the experiment in 1992. Since it was early in the experiment, the ewes of the dead lambs were removed from the paddock and another ewe and lamb pair were substituted to maintain similar stocking rates.

Data were analyzed using analysis of variance techniques (SAS, 1990). The model for ewe data included treatment, pasture nested within treatment, number of lambs reared and ewe age; with birth date as a covariate. The model for lamb data included treatment, paddock nested within treatment, lamb sex and number of lambs reared; with birth date as a covariate. Paddock nested within treatment means square was used as an error term to test treatment.

Results and Discussion

Weather and Forage Availability and Quality

Ambient air temperatures from April through August typically exceeded the 30-year average in 1992, while in 1993 ambient air temperatures were lower than the 30-year average from June through August (Table 2). Rainfall occurring from April through August exceeded the 30-year average by 36% and 81% in 1992 and 1993, respectively (Table 1). Precipitation was adequate both years to sustain active alfalfa and orchardgrass growth during the growing season.

Total forage DM yield (pounds per acre), crude protein concentration and NDF for grazing periods in 1992 and 1993 are shown in Table 2. It has been reported that rotational stocking increases plant growth compared to continuous grazing (Chapman et al., 1983). These findings are supported by results reported from this study. The RS paddocks tended to have higher forage DM yields (pounds per acre) compared to CS paddocks. Average forage CP content during the summer exceeded the CP requirement of ewes suckling twins during the first eight weeks of lactation (National Research Council [NRC], 1985).

Animal Response – 1992

Stocking rates when expressed as sheep per acre or pound per acre did not differ ($P > 0.10$; Table 3). Grazing days per acre did not differ ($P > 0.10$) between grazing treatments; however, grazing days per acre tended to be lower for ewes and higher for lambs in the RS treatment compared with CS. This was due to lower ewe stocking rates and higher lamb stocking rates at the beginning of the experiment. Ewe daily gain was higher ($P < 0.01$) for RS compared to CS. Greater weight gain by SDG ewes may be explained by more available forage of higher quality when compared to CS (Table 2). For example, RS treatments had 3,668 pounds per acre of available forage that contained 15.8% CP and 49.9% NDF on June 28, while CS pastures had only 2,379 pound per acre of available forage that contained 15.5% CP and 52.5% NDF.

Ewe weight gain in both grazing treatments may have been affected by level of milk production. Ewes were 30 days into lactation at the beginning of the experiment and were probably in the declining phase of their milk production curve. Therefore the combination of a high quality and high quantity of forage and the lower nutrient requirements for milk production were probably responsible for the weight gains which compensated for previous losses during the first month of lactation.

Lamb daily gain was greater (P < 0.05) for the CS treatment (Table 3). Volesky et al. (1990) reported higher daily gains for calves and lambs under CS grazing compared with RS; however, gain per acre was greater in the RS system due to greater stocking rate. Ewe and lamb gain per acre was similar (P > 0.10) between treatments in this study. This was due to less ewe and more lamb grazing days on the RS pastures compared with CS paddocks, which offset the higher ewe daily gain and lower lamb daily gain in the RS paddocks. Lamb gains of 0.61 to 0.69 pounds per day indicated satisfactory forage availability and quality and a high level of sustained ewe milk production.

Animal Response – 1993

Ewe and lamb stocking rates were increased to 3.6 ewes and 6.5 lambs per acre (Table 4). Average initial ewe stocking rate was approximately 498 pounds per acre. Lamb initial stocking rate was 196 pounds per acre, which was 73 pounds per acre greater than in 1992. Ewe and lamb grazing days did not differ (P > 0.10) between treatment groups with 289 ewe and 521 lamb grazing days per acre (Table 4). This was approximately the same number of ewe and lamb grazing days as in 1992.

Ewe average daily gain and gain per acre were greater (P < 0.01) for RS than for CS. Greater ewe gain with RS probably resulted from higher forage availability and higher quality in the RS paddocks. Forage available on June 30 in the RS pastures was 3,770 pounds per acre while the CS averaged 2,730 pounds per acre. At the end of the summer grazing season (August 13), RS pastures averaged 2,971 pounds per acre compared to 1,869 pounds per acre in the CS paddocks. Average ewe daily gains in 1993 were less than 1992 (0.13 vs. 0.28 pounds per day). This may be due to the colder, wetter weather that persisted in 1993 and more total animal units per acre.

Lamb daily gain and gain per acre were similar (P > 0.10) between treatments (0.56 pounds per day CS vs. 0.54 pounds per day RS; 280.6 pounds per acre CS vs. 255.1 pounds per acre RS). Experiments where stocking rates were equal for both CS and RS systems have resulted in similar animal gain (Sharrow and Krueger, 1979). However, forage availability was greater under the RS system (Sharrow 1983). Fecal egg counts were higher (P < 0.01) for RS lambs than CS lambs (Table 4). However, fecal egg counts were rela-

Table 3. Effect of grazing system on ewe and lamb performance (1992).

	Grazing system		
Item	Continuous	Rotation stocking	SE[a]
Ewes:			
Stocking rate, ewes per acre	3.3	2.9	0.3
Initial stocking rate, pounds per acre	568.8	450.1	36.1
Grazing days per acre	295.6	271.5	20.8
Initial BW, pounds	146.7	137.5	3.7
Final BW, pounds	168.9	169.6	3.5
Daily gain, pounds per day[b]	0.24	0.31	0.03
Gain, pounds per acre	66.1	73.6	3.7
Lambs:			
Stocking rate, lambs per acre	5.2	5.9	0.5
Initial stocking rate, pounds per acre	122.8	129.5	7.6
Grazing days per acre	446.9	547.9	51.3
Initial BW, pounds	23.5	21.3	0.9
Final BW, pounds	82.3	77.7	1.6
Daily gain, pounds per day[c]	0.69	0.61	0.02
Gain, pounds per acre	307.6	330.9	13.8

[a] SE = standard errors of least square means.
[b] Treatments differ (P < 0.01).
[c] Treatments differ (P < 0.05).

Table 4. Effect of grazing system on ewe and lamb performance (1993).

	Grazing system		
Item	Continuous	Rotation stocking	SE[a]
Ewes:			
Stocking rate, ewes per acre	3.6	3.5	0.2
Initial stocking rate, pounds per acre	518.6	477.1	6.9
Grazing days per acre	294.4	283.6	14.8
Initial BW, pounds	147.6	142.1	3.3
Final BW, pounds	152.4	157.5	3.3
Daily gain, pounds per day[b]	0.06	0.19	0.02
Gain, pounds per acre[b]	19.6	57.8	2.9
Fecal egg counts, eggs per gram	1.57	8.0	3.0
Lambs:			
Stocking rate, lambs per acre	6.5	6.4	0.10
Initial stocking rate, pounds per acre	188.6	203.6	3.7
Grazing days per acre	529.2	512.7	10.9
Initial BW, pounds	30.6	32.6	0.31
Final BW, pounds	76.1	75.0	4.6
Daily gain, pounds per day	0.56	0.54	0.01
Gain, pounds per acre	280.6	255.1	31.4
Fecal egg counts, eggs per gram[b]	60.1	109.6	4.2

[a] SE = standard errors of least square means.
[b] Treatments differ (P < 0.01).

tively low and well below the level of about 500 eggs per gram of feces indicated for treatment (Tritschler and Fenton, 1989). Weather conditions during the summer grazing season in 1993 were wet and cool, with a minimal number of sunny days; consequently, RS paddocks never dried out during the summer and the sheep were probably exposed to greater numbers of larvae in 1993 than in 1992.

Ewes and lambs were selective in the plant parts they consumed. Ewes and lambs first consumed the leaves and upper portions of the stems. New growth arising from the crowns was grazed while mature stems remained ungrazed. Jagusch et al. (1970) and Lane and Apoundrecht (1991) observed these same selection patterns in lambs.

Conclusions

A high level of productivity can be achieved with ewes and lambs grazing dryland alfalfa and orchardgrass during the spring and summer in Montana. Lambs in this trial gained an average of 0.55 and 0.65 pounds per day or 268 and 319 pounds per acre for 1992 and 1993, respectively.

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Immune Response and Performance of Sheep Fed Supplemental Zinc as Zinc Oxide or Zinc Methionine[1]

E.B. Kegley[2] and J.W. Spears[2]

Summary

Sixty-eight pregnant Suffolk crossbred ewes were used to assess the effects of source of supplemental zinc (Zn) on ewe and lamb performance and post-weaning immune response of lambs. Ewes were stratified by age and randomly assigned to treatment. Treatments consisted of 50 mg per ewe daily of supplemental Zn from either zinc oxide (ZnO) or zinc methionine (ZnMet). Ewes received supplements for 30 to 60 days prior to lambing and until weaning. Ewe weights at weaning were not affected by treatment. Lamb average daily gain (ADG) to day 83 of the study tended to be greater ($P < 0.15$) for lambs in the ZnMet supplemented group (0.29 vs. 0.27 kg/day). However, adjusted 50-day weaning weights were not affected by treatment. Immediately following weaning (average age = 46 days), 12 lambs (6 per treatment) were shipped approximately 350 km. Upon arrival lambs were penned individually and fed diets supplemented with 25 mg of Zn per kilogram from either ZnO or ZnMet. Three days following transport, unstimulated lymphocytes from lambs supplemented with ZnMet had a greater ($P < 0.06$) *in vitro* blastogenic response compared with those from lambs supplemented with ZnO. Blastogenic responses of lymphocytes when stimulated with phytohemagglutinin, concanavalin A or pokeweed mitogen were not affected by treatment. Five days after arrival there were no treatment differences in peak response to an intradermal injection of phytohemagglutinin 4, 8, 12, 22, 26 and 32 hours after injection. However, lambs supplemented with ZnMet had a smaller ($P < 0.07$) welt diameter 46, 56 and 70 hours post-injection. Average daily gain, feed intake and gain/feed were similar across treatments for the 14 days following transport. Supplemental ZnMet tended to improve preweaning lamb gain and some aspects of the immune response of stressed lambs when compared with supplemental ZnO.

Key words: zinc, sheep, immune response.

Introduction

Zinc is an essential trace element for ruminants (Mills et al., 1967). The Zn requirement for sheep is currently estimated to be 20 to 33 mg Zn/kg DM (NRC, 1985). Under practical conditions, severe Zn deficiency is rare, but marginal Zn deficiencies may occur. Zinc supplementation of practical ruminant diets that contained 25 mg Zn/kg has sometimes improved growth rate and reproductive performance (Masters and Fels, 1980; Price and Humphries, 1980).

Stress decreases plasma Zn with a redistribution of Zn from the plasma to the liver (Beisel et al., 1976). There is little data on whether Zn requirements change during stress. A severe Zn deficiency does cause immunosuppression (Droke and Spears, 1993).

Different sources of Zn may have differing effects, either through differences in absorption or metabolism. In lambs, Spears (1989) reported that zinc oxide (ZnO) and zinc methionine (ZnMet) were absorbed to a similar extent, but appeared to be metabolized differently after absorption. In cattle, supplemental ZnMet has improved some aspects of the immune response when compared to ZnO. In stressed feeder calves, supplemental ZnMet increased titers to

[1] The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Station of the products named or criticism of similar ones not mentioned.

[2] Department of Animal Science and Interdepartmental Nutrition Program, North Carolina State University, Raleigh, NC 27695-7621.

bovine herpesvirus-1 following vaccination (Spears et al., 1991).

Therefore, the objectives of this study were to determine the effects of source of supplemental Zn (ZnO or ZnMet) on: 1) ewe and lamb performance; and 2) the postweaning immune response of lambs.

Materials and Methods

Sixty-eight pregnant ewes were stratified by age and randomly assigned to treatments. Ewes were predominately of Suffolk breeding and were bred to Suffolk rams. Treatments consisted of 50 mg per ewe daily of supplemental Zn as ZnO (Eastern Mineral Corporation, Henderson, NC) or as ZnMet (Zinpro, Edina, MN). Ewes were fed the supplemental Zn mixed with corn meal prior to the morning feeding. Ewes were also fed a corn-urea-mineral-vitamin supplement (30 mg Zn/kg) formulated to meet all NRC mineral and vitamin requirements with the exception of Zn. In addition, ewes were offered corn silage (26 mg Zn/kg) and alfalfa hay or alfalfa haylage (23 mg Zn/kg) on an ad libitum basis.

The study was initiated January 25, 1989, at the Upper Mountain Research Station in Laurel Springs, NC. Lambing took place from February 25 until March 26, 1989; 78% of the ewes lambed. Data from ewes that did not lamb were not included in the analysis. Lambs were weaned on two days, April 18, 1989, (34 lambs) and May 16, 1989, (33 lambs). Lambs were not offered creep feed, but could eat from the ewes' trough. An adjusted 50-day weaning weight was calculated for the lambs as [(weaning weight - birth weight) × 50/age at weaning] + birth weight. Ewes and lambs were weighed before feeding at 28-day intervals throughout the study. Supplements were fed from 30 to 60 days prior to lambing until the lambs were weaned. Lamb birth weights were obtained and the ease of birth and condition at birth were scored subjectively.

Table 1. Composition of diets fed to weaned lambs (DM basis).

Item	Amount, %
Corn	47.78
Soybean meal	20.12
Cottonseed hulls	30.51
Salt	0.45
Vitamin premix[a]	0.02
Limestone	1.12
Mineral premix[b]	–

[a] Vitamin premix contained 9,900,000 IU vitamin A, 3,300,000 IU vitamin D_3 and 3,300 IU vitamin E per kilogram.

[b] Trace mineral premix provided in mg per kilogram diet: 23 Mn (MnO), 10 Cu ($CuSO_4 \cdot 5H_2O$), 0.13 Se (Na_2SeO_3), 0.05 Co ($CoCl_2$) and 0.7 I (KI).

Twelve lambs (six per treatment) were weaned early, at an average age of 46 days. They were immediately shipped approximately 350 km to Raleigh, NC. Lambs were penned individually in 1.52 m^2 pens and fed diets supplemented with 25 mg Zn/kg DM from ZnO or ZnMet. Lambs remained on the same supplemental Zn source as their dams. Lambs were allowed to consume the diets ad libitum. The diets (Table 1) were analyzed to contain 55 mg Zn/kg DM. Lambs were weighed on day 0 and 14 postweaning. Feed intake was recorded daily throughout this 14-day period. Blood was collected on day 0, 4, 10 and 14 for serum Zn and Cu analysis by atomic absorption spectrophotometry (Model 5000; Perkin-Elmer, Norwalk, CT).

Three days after transport, blood was collected and the blastogenic response of peripheral lymphocytes to phytohemagglutinin (PHA; 25 µg/ml; Sigma Chemical Company, St. Louis, MO), concanavalin A (ConA; 25 µg/ml; Sigma Chemical Company, St. Louis, MO) and pokeweed mitogen (PWM; 40 µg/ml; Sigma Chemical Company, St. Louis, MO) was measured using ^{3}[H]-thymidine, as described by Ward et al. (1993). Triplicate cultures from each animal with each mitogen were supplemented with 25 µl of serum that was pooled within each treatment.

As a means of assessing the humoral immune response, four days after transport lambs were injected intramuscularly with 300 µg lysozyme in 0.5 ml phosphate buffered saline (PBS). Serum was collected for titer determination on days 4, 8 and 14 postweaning, which corresponds to days 0, 4 and 10 postinjection. Lysozyme immuno-globulin titers were determined using an enzyme-linked immunosorbent assay (Droke and Spears, 1993). Blood was collected on day 4 into tubes containing ethylenediaminetetraacetic acid (EDTA) for determination of differential white cell count.

As an *in vivo* means of assessing cell mediated immune response, five days after transport the lambs' ability to respond to an intradermal injection of PHA was measured. The injection site was on the lamb's side immediately posterior to the scapula. The site was shaved with surgical clippers and 150 µg PHA in 0.1 ml PBS was injected intradermally. Welt diameter was measured 4, 8, 12, 22, 26, 32, 46, 56 and 70 hours postinjection using micrometric calipers (Fisher Scientific, Pittsburgh, PA).

Data were analyzed by least squares ANOVA using the GLM procedures of SAS (SAS, 1988). The model for preweaning lamb performance included treatment, sire, sex, number in litter and date of birth. The model for ewe performance included treatment and lambing date; the model for postweaning lamb performance and immune response data included treatment. The model for serum Zn and Cu included treatment, sampling day and the sampling day × treatment interaction.

Results and Discussion

Ewe weights at weaning were not affected by source of supplemental Zn (Table 2). Average daily gain was higher ($P < 0.01$) for ewes fed supplemental ZnO than those supplemented with ZnMet during the first 28 days (0.106 vs. 0.014 kg). However, over the entire 111-day study, ewe weight change was not affected by supplemental Zn source. Ease of birth scores were improved ($P < 0.07$) for ewes supplemented with ZnMet.

Lamb condition at birth and birth weight (Table 2) were not affected by supplemental Zn source. Lamb average daily gain was greater ($P < 0.01$) from days 0 to 69 of the study and tended to be greater ($P < 0.15$)

from days 0 to 83 for lambs whose dams were fed supplemental ZnMet compared with those fed ZnO. However, lamb adjusted 50-day weaning weight was not affected by supplemental Zn source. Supplemental ZnMet appeared to improve the performance of young lambs, but at weaning there were no differences in performance due to supplemental Zn source. The sheep in the present study were receiving forages with a Zn content of greater than 23 mg/kg and this may have masked any differences in bioavailability of the sources. Masters and Fels (1980) observed a 14% increase in number of lambs born and an increased lamb survival rate when Zn was supplemented throughout mating, pregnancy and lactation. Birth weight in that study was increased by supplemental Zn. However, in later experiments (Masters and Fels, 1985), consistent improvements to supplemental Zn were not observed and the authors proposed that factors other than Zn were involved. Adding supplemental Zn increased calf weight gains when cows and calves were grazing forages containing less than 20 mg Zn/kg (Mayland et al., 1980). Cattle provided a free choice mineral mix containing two-thirds of the Zn and Mn in the methionine form weaned heavier calves than those provided a free choice mineral with all the Zn and Mn in the oxide form (Spears and Kegley, 1991).

Following weaning and transport, lamb average daily gain, feed intake and gain/feed were not affected by source of supplemental Zn (Table 3). There was no effect of source of supplemental Zn on serum Zn following weaning and transport (Table 3). All of these values are within what is considered to be normal. However, there was a significant effect of source of supplemental Zn on serum Cu following weaning and transport (Table 3). On days 0, 4, 10 and 14, serum Cu was greater ($P < 0.01$) in lambs fed ZnO compared with ZnMet. Serum Cu increases during stress (Conforti et al., 1982; Stabel et al., 1993) and these lower values may indicate that lambs supplemented with ZnMet were not as stressed as lambs supplemented with ZnO.

Source of supplemental Zn did not affect blastogenic response of lympho-

Table 2. Effect of zinc oxide or zinc methionine supplementation on performance of ewes and lambs until weaning.

Item	Zinc oxide (no. of observations)	Zinc methionine (no. of observations)	SEM
Ewe weight, kg:			
Initial, January 25	76.1 (25)	78.7 (27)	3.29
At weaning, April 18 or May 16	70.7 (22)	72.2 (23)	2.99
Ease of birth[a]	1.3[b] (43)	1.1[c] (47)	0.08
Lamb condition at birth[d]	1.8 (43)	1.6 (47)	0.17
Lamb birth weight, kg	5.1 (43)	4.8 (47)	0.15
Lamb average daily gain, kg:			
Day 0 to 69, April 4	0.27[e] (32)	0.33[f] (36)	0.016
Day 0 to 83, April 18	0.27 (31)	0.29 (36)	0.013
Adjusted 50-day weaning weight, kg	20.1 (31)	20.3 (36)	0.63

[a] Ease of birth scored on a scale of 1 to 4, with 1 being an unassisted birth and 4 being a difficult birth.
[b,c] Means within a row with different superscripts differ ($P < 0.07$).
[d] Lamb condition at birth scored on a scale of 1 to 5, with 1 being a strong lamb and 5 being the weakest.
[e,f] Means within a row with different superscripts differ ($P < 0.01$).

Table 3. Effect of zinc oxide or zinc methionine supplementation on performance and serum Zn and serum Cu of stressed lambs.

Item	Zinc oxide	Zinc methionine	SEM
Initial weight, kg	21.0	22.7	2.01
Average daily gain, kg	0.28	0.25	0.058
Daily feed intake, kg	0.65	0.61	0.079
Gain/feed	0.38	0.41	0.079
Serum Zn, mg/L	0.84	0.89	0.042
Serum Cu, mg/L	1.04[a]	0.82[b]	0.028

[a,b] Means within a row with different superscripts differ ($P < 0.01$).

Table 4. *In vitro* blastogenic response of peripheral blood lymphocytes from stressed lambs supplemented with zinc oxide or zinc methionine.

Item	Zinc oxide, CPM × 10^3	Zinc methionine, CPM × 10^3	SEM, CPM × 10^3
Unstimulated	0.4[a]	1.1[b]	0.21
Phytohemagglutinin, 25 μg/ml	139.5	119.8	17.14
Concanavalin A, 25 μg/ml	144.1	120.4	23.57
Pokeweed mitogen, 40 μg/ml	118.5	77.3	23.47

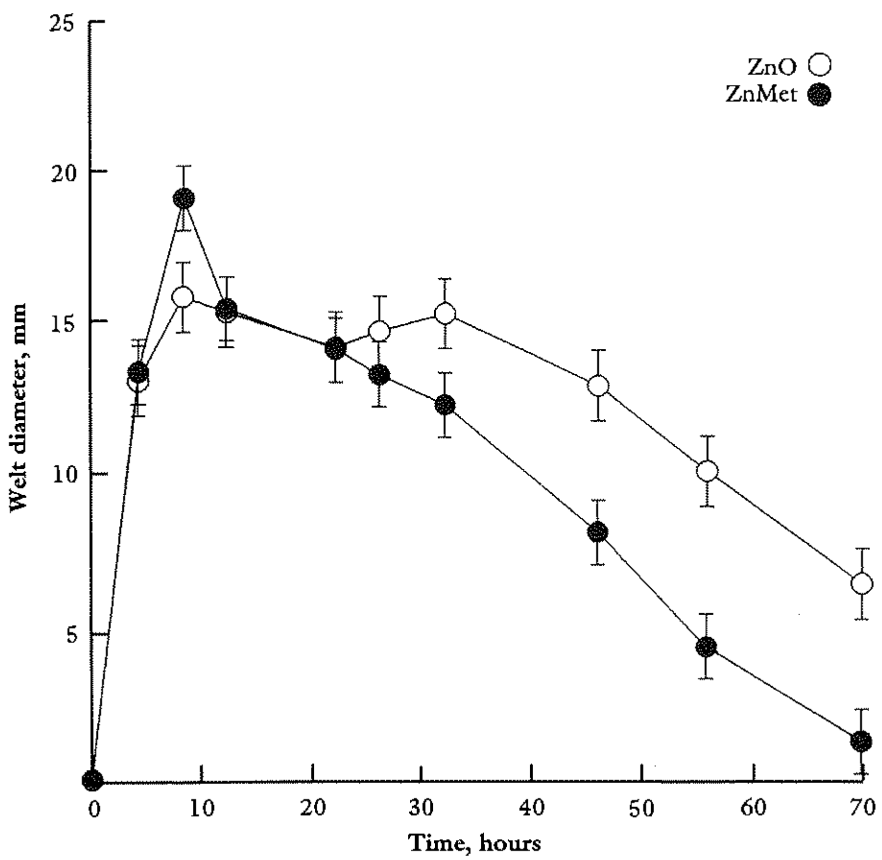
[a,b] Means within a row with different superscripts differ ($P < 0.06$).

cytes cultured with PHA, ConA or PWM (Table 4). However, in the unstimulated cultures, ^{3}[H]-thymidine incorporation was higher ($P < 0.06$) for lymphocytes obtained from lambs fed ZnMet. A severe Zn deficiency decreased the blastogenic response of lamb lymphocytes to a suboptimal concentration of PHA, but increased the response to a superoptimal concentration of PWM (Droke and Spears, 1993). However, marginally deficient lambs did not differ from Zn-adequate lambs in their response (Droke and Spears, 1993).

In vivo peak response to the intradermal PHA injection occurred between 4 and 8 hours postinjection and was not affected by supplemental Zn source (Figure 1). However, the rate at which the inflammation decreased was affected by a treatment × time interaction ($P < 0.01$). Lambs fed ZnMet had a more rapid decrease in the inflammatory response which may indicate that they were able to clear the antigen more rapidly.

Neither IgM nor IgG antibody titers to lysozyme were affected by treatment. Differential white cell counts four days after weaning and transport were also not affected by treatment (data not shown).

Figure 1. Effect of zinc oxide or zinc methionine supplementation on *in vivo* cell mediated response. Lambs were injected intradermally with phytohemagglutinin five days after weaning and transport. There was a significant time × treatment interaction ($P < 0.01$).



Conclusions

Supplemental zinc methionine tended to improve lamb gain before weaning. Some aspects of the immune response of stressed lambs, in particular the ability to clear the intradermal PHA injection, also were improved by zinc methionine supplementation.

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Supplementing Ewe Diets with the Calcium Salts of Palm Oil Fatty Acids during Lactation[1]

L.A. Appeddu[2], D.G. Ely[2,3], D.K. Aaron[2], W.P. Deweese[2] and E. Fink[2]

Summary

Sixteen fall-lambing Polypay ewes nursing twin lambs were fed a control (C) lactation diet of alfalfa hay, cracked corn and soybean meal or the same diet supplemented (S) with 4.1% calcium salts of palm oil fatty acids (CaSPO) to determine the effects on ewe body weight (BW) change, milk production and composition and lamb performance. Ewes were randomly allotted to individual pens and fed isonitrogenous and isocaloric C and S diets from 19 to 54 days postpartum. Lambs were not creep fed and did not have access to ewe feed. Ewes were machine-milked to estimate 24-hour milk production (MP) on days 19, 26, 33, 42 and 56 postpartum. Ewe and lamb BW were recorded on the same day. Milk sample analysis of dry matter (DM), fat (MF) and protein (MPR) were used to calculate 24-hour component yields and production efficiencies per ewe dry matter intake (DMI). Gain for S ewes was higher (1.45 vs. 0.17 kg; $P < 0.10$) from days 42 to 54 and tended to be higher for the entire lactation period. On average, no treatment differences were found for daily MP, DM%, DM yield, MF%, MF yield or MPR yield. However, CaSPO supplementation tended to increase percentages and yields of DM and MF, but decrease MPR yields, by days 42 and 54. An overall decrease (21.25 vs. 22.48%; $P < 0.09$) in MPR% was found with CaSPO supplementation. Milk and component yields per ewe DMI were similar. Lamb average daily gain (ADG), overall gain, adjusted 60-day weaning weights and efficiency of lamb gain per ewe were similar for both treatments. Although CaSPO supplementation increased ewe gains and positively influenced DM and MF in late lactation, neither lamb performance nor production efficiency was enhanced.

Key words: fat, fatty acids, milk, ewe, lamb.

Introduction

Lactation places the highest metabolic demands on the ewe (Coppock and Wilks, 1991; National Research Council [NRC], 1985; Bauman and Currie, 1980) because of requirements for maintenance, milk production and possibly growth and reproduction. Consequently, body reserves and nutrient intake may not be sufficient to support all needs, especially in prolific ewes during peak lactation. This negative nutrient balance may cause lower milk production, decreased lamb performance and, potentially, metabolic disorders (Littledike et al., 1981).

Energy and protein are the nutritional factors identified as most limiting for milk production (Clark et al., 1992). Development of rumen inert lipids to increase dietary energy density has alleviated diet handling and fiber digestibility problems associated with feeding either high-concentrate diets or untreated lipids and oil seeds (Grummer et al., 1990). Megalac is the calcium salts of palm oil fatty acids (CaSPO; Church and Dwight Company, Inc., Princeton, NJ). It remains virtually inert until reaching the small intestine, so it does not adversely affect ruminal microbial activity (Wu et al., 1993; Wu and Palmquist, 1991; Schauff and Clark, 1989). Furthermore, these dietary fatty acids are readily available for intestinal digestion, absorption and, subsequently, direct incorporation into milk fat triglycerides, which improves milk production (Chilliard, 1993; Grummer, 1991; Kronfield, 1982). Increases in milk production and fat yields in dairy cows supplemented with CaSPO have been

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[2] Department of Animal Sciences, University of Kentucky, Lexington, KY 40546-0215.

[3] Send reprint requests to: Room 904, W.P. Garrigus Building, University of Kentucky, Lexington, KY 40546-0215.

reported, but milk protein content may decrease (Cant et al., 1993; Coppock and Wilks, 1991; Canale et al., 1990). This experiment was conducted to: 1) determine if CaSPO supplementation alters ewe BW change, milk production or milk composition; and 2) evaluate subsequent effects on lamb performance.

Materials and Methods

Sixteen fall-lambing Polypay ewes (three to six years of age), each with twin lambs, were randomly allotted to two dietary treatments. The control (C) diet was formulated to meet NRC (1985) lactating ewe nutrient requirements (Table 1). To formulate the test diet (supplemented [S]), portions of hay and corn were replaced with 4.1% CaSPO, soybean meal was slightly increased and a one-to-one roughage-to-concentrate ratio was maintained. Ewes were weighed (average weight= 72.5 kg) and allotted to dietary treatments 15 days (average) postpartum (day 8 to 21 range). Each ewe and her lambs were individually penned (1.2 × 8.0 m) in an open-sided barn. Minimum amounts of straw were used for bedding on a dirt floor.

Prior to allotment to the study, ewes had received a daily ration of 1.8 kg alfalfa hay and 0.7 kg shelled corn. Ewes were adjusted to diets by feeding increasing amounts of experimental diets each day from day 15 through 19. The C and S diets were offered at 3.69% and 3.54% (DM basis), respectively, of individual initial BW from day 19 to day 54 of lactation. Diets at these levels produced isocaloric and isonitrogenous intakes. The complete diets were fed in equal amounts twice daily at 0800 and 1600 hours. Lambs were separated from ewes for 60 minutes at each feeding. Any feed remaining after this period was recovered, weighed and discarded before lambs were allowed to re-join ewes. Samples of ewe diets were collected weekly, composited and ground through a 1-mm screen in a Wiley mill. Subsamples were quantified for DM, ash, ADF, NDF, lignin, ether extract (acid hydrolysis method) and gross energy (GE) by the Association of Official Analytical Chemists procedures (AOAC; 1990). Crude protein was determined with a macro N Analyzer, which automates the Dumas method (AOAC, 1990).

Ewes and lambs were individually weighed immediately prior to 1000 hours on days 19, 26, 33, 42 and 54 of lactation. Lambs were separated from ewes immediately after weighing. Ewes then received a 1-cc intravenous injection of oxytocin and were immediately machine-milked. This milk was discarded. After a 4-hour separation period, ewes received a second oxytocin injection and were milked again. These milk weights were multiplied by six to estimate 24-hour milk production (MP).

Milk samples were refrigerated at 4 °C until analyzed for DM% (total solids) using a modified procedure of AOAC (1990). Modification included warming fresh milk samples to 45 °C for mixing, weighing into aluminum pans and then freezing at –20 °C until DM analysis was conducted. A portion of each collection was preserved with bronopol and shipped to Milk Marketing, Inc., in Strongsville, OH, for determination of fat (MF) and protein (MPR) via infrared analysis (AOAC, 1990). From these results, 24-hour DM, MF and MPR yields were calculated by multiplying component percentages by 24-hour MP estimates. Daily records of ewe DMI were used to calculate efficiencies of MP, DM, MF and MPR yields for each milk collection day.

Ewe BW change and lamb ADG were determined from weights recorded on milk collection days. Lamb weights taken on day 54 were adjusted to 60-day values for sex, type of birth and ewe age by the procedures of the Sheep Industry Development Program (SID; 1988). Lamb ADG per ewe DMI was also calculated.

Data were statistically analyzed, using the GLM procedure of SAS (SAS; 1985), as a completely randomized design with a one-way treatment structure and repeated measures over time. Ewe was considered the experimental unit. The error term for testing treatment differences was ewe nested within treatment. Linear, quadratic, cubic and quartic contrasts were performed to delineate effects of time of collection during the 35-day experimental period. Twin lamb data were added together to evaluate lamb performance as a function of the ewe. Treatment differences for overall lamb gain and 60-day adjusted weaning weight (WW) were analyzed using a one-way analysis of variance.

Results and Discussion

The chemical composition of diets and average ewe daily DMI are reported in Table 2. The S diet was slightly higher in protein and energy, justifying the feeding of a higher percentage of C diet (3.69 vs. 3.54% of initial BW). Actual DMI was slightly lower (3.48% and 3.43% of initial BW for C and S diets, respectively), but nutrient intakes remained similar. Digestible energy intake in

Table 1. Ingredient composition of ewe lactation diets.

	Treatment	
Ingredient	C[a],%	S[b],%
Ground alfalfa hay	49.7	46.3
Cracked corn	36.3	33.5
SBM (48% CP)	9.0	11.4
Liquid molasses	4.5	4.2
TMS + Se[c]	0.5	0.5
CaSPO[d]	—	4.1

[a] C = control.
[b] S = CaSPO-supplemented.
[c] Trace mineral salt: 95% to 98.5% NaCl; > 0.35% Zn; > 0.34% Fe; > 0.20% Mn; > 0.033% Cu; > 0.007% I; > 0.005% Co; 90 ppm Se.
[d] CaSPO = calcium salts of palm oil fatty acids (Megalac; Church and Dwight Company, Inc., Princeton, NJ; 87.19% fat on DM basis).

both treatments was calculated to meet the requirements for a 70-kg ewe nursing twin lambs during the first six to eight weeks of lactation (NRC, 1985). Additionally, CaSPO supplementation effectively increased fat, while decreasing fiber content of the S diet, resulting in a higher fat intake by S ewes (0.18 vs. 0.10 kg per day). Supplementation with 4.1% CaSPO falls within the recommended dietary levels (3 to 6%) shown to optimize milk production of does (Teh et al., 1994) and dairy cows (Schauff and Clark, 1992) without detrimental effects on digestion.

Supplementation with CaSPO did not decrease ewe DMI. In contrast, Grummer et al. (1990) found CaSPO was less acceptable to dairy cows than three other fat supplements. Palmquist and Kelbly (1993) found acceptability by dairy cows of grain mixes containing CaSPO to increase linearly over time. These studies indicate the need to adapt animals to CaSPO. However, palatability may not be the sole cause of reduced dietary intakes. Decreased DMI was found in dairy cows abomasally infused with both saturated and unsaturated fatty acids (FA; Christensen et al., 1993), suggesting a possible metabolic effect of fat supplementation. Reduced intakes of CaSPO-supplemented diets may negate any possibility of increasing energy intakes, disallowing subsequent improvements in lactational performance (Schauff and Clark, 1992). By first adjusting ewes to diets and then controlling intakes at 3.69 and 3.54% of BW in the present experiment, total dietary intake reduction may have been prevented or the supplemental fat may have been diluted enough by other dietary ingredients to avoid any metabolic effects on intake. Other work has shown no decreases in DMI with CaSPO supplementation (Hightshoe et al., 1991; Canale et al., 1990; Grummer, 1988).

Ewe weight change (Figure 1) from days 19 to 54 postpartum followed a quadratic trend ($P < 0.01$), with weight losses for both C and S ewes occurring from days 26 to 33. After maintaining weight from 33 to 42 days postpartum, S ewes gained more ($P < 0.10$) than C ewes from 42 to 54 days (1.45 vs. 0.17 kg per ewe). The S-fed ewes gained an average of 1.14 kg per head for the 35-day period, whereas C ewes lost 0.17 kg per head. These differences were not statistically significant. Kronfield et al. (1980) reported dairy cows fed ruminally protected tallow gained weight, whereas control cows lost weight. However, Schingoethe and Casper (1991) found no reduction in weight loss with the addition of fat to the diet in early lactation. Instead, the metabolic processes of early lactation partitions nutrients to milk synthesis rather than body storage (Palmquist et al., 1993a; Bauman and Currie, 1980). As lactation progresses, smaller amounts of nutrients are directed to the mammary gland and more to adipose tissue (Bauman and Currie, 1980).

Initial MP on day 19 postpartum was equal between treatments (2.71 kg per 24 hours; Table 3). Numerically, highest production, found on day 26, was followed by a general decline through day 54. Overall, MP for both treatments decreased linearly ($P < 0.01$) with time. The loss of ewe BW from day 26 to 33 (Figure 1), relative to the period of highest MP (Table 3), supports the conclusions of Schingoethe and Casper (1991) that supplemental dietary fat does not decrease weight loss during early lactation. Sklan et al. (1991) concluded that most of the energy in supplemental dietary fat is channeled into milk so there is no reduction in body weight loss in dairy cows during peak production. Furthermore, weight gain of S ewes ($P < 0.10$) from day 42 to 54 (Figure 1) agrees with Palmquist et al. (1993a) in that as lactation progresses, more nutrients are directed to weight gain and less to MP.

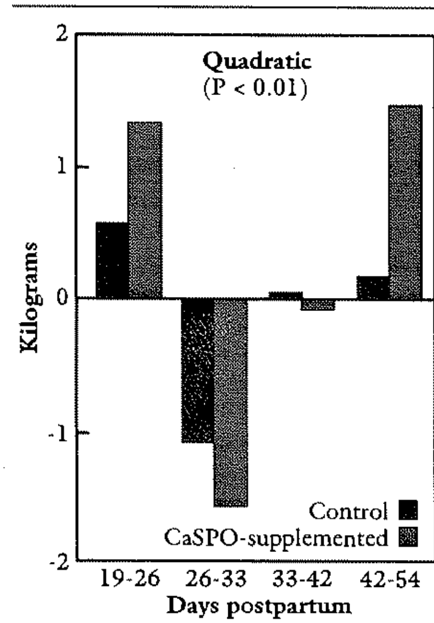
In contrast with MP, DM% increased linearly ($P < 0.01$) as lactation length increased (Table 3). Milk of S ewes

Table 2. Chemical composition and daily dry matter intake of lactation diets.

	Treatment	
Ingredient	C[a]	S[b]
Component:		
DM	93.1	93.1
CP[c]	17.6	18.3
Fat[c]	4.0	7.1
NDF[c]	31.6	27.9
ADF[c]	20.6	18.2
Lignin[c]	3.8	3.0
Ash[c]	6.9	7.2
GE, Mcal/kg DM	4.4	4.4
Daily DMI, kg/ewe	2.49	2.52

[a] C = control.
[b] S = CaSPO-supplemented.
[c] Percent of DM.

Figure 1. Body weight change by period for ewes fed control and CaSPO-supplemented diets.



tended to have a higher DM%, particularly in late lactation (P = 0.12 on day 54). However, overall mean DM% was not affected by treatment. The tendency for C ewes to produce more fresh milk and S ewes to produce milk with a higher DM content resulted in similar DM yields per 24 hours. Production of DM followed a cubic trend (P < 0.10) with peaks on day 33 and 26 for C and S ewes, respectively.

The potential to increase both MP and DM yield may have been limited by the short period between initiation of CaSPO supplementation and peak MP. Ewes began receiving diets on day 15 postpartum and MP peaked on day 26 (Table 3). Schauff et al. (1992), Hoffman et al. (1991) and Schingoethe and Casper (1991) found a slow response to fat supplementation in terms of increasing milk yields. Specifically, Tomlinson et al. (1994) reported that yield increases were not evident before the fourth week of feeding CaSPO. Responses to lipid supplementation in dairy cow diets are greatest in early lactation and in the highest producers (Schauff and Clark, 1992). Thus, the time required for CaSPO to initiate a MP response is probably longer than the eleven days between first feeding and the period when it would have been best utilized (peak production). Furthermore, Polypay ewes used in this experiment were not specifically selected for high MP. A lower genetic potential for high MP, combined with a shorter lactational period and earlier time of peak MP, may limit the potential of dietary CaSPO to increase MP of ewes.

Another reason why neither MP nor DM yield was increased by CaSPO supplementation may be due to the experimental procedures employed. Both C and S diets were high-quality, contained similar ingredients, were similar in chemical composition and were fed to provide isocaloric and isonitrogenous intakes. In contrast, Teh et al. (1994) reported that most studies in which increases in MP or DM yield were found may have been confounded with increased energy intakes because dairy cows were allowed ad libitum access to CaSPO-supplemented lactation diets. On the other hand, milk yield increases are seldom observed when intakes are isocaloric (Teh et al., 1994; Schauff and Clark, 1992; Schauff et al., 1992).

Body condition at parturition also influences responses of cows to CaSPO. Garnsworthy and Huggett (1992) found that milk yields of thin cows tended to increase when CaSPO was fed. Cows in better condition maintained condition and produced milk with a higher percentage of fat, but overall MP was not increased. Both C and S ewes in this experiment carried a moderate amount of condition at lambing and tended to maintain this condition throughout lactation, as evidenced by no extreme weight losses. Although no differences between C and S were found for MP, milk of S ewes contained a numerically higher fat percentage on day 42 and significantly more (P < 0.10) on day 54 (Table 3).

The tendency for increased DM% in S milk during the latter part of the experimental period coincides with higher MF% (Table 3). Percent MF increased linearly (P < 0.05) across treatments from day 19 to 54 postpartum for both treatments. Although MF yield differences were not significantly affected by treatment or lacta-

Table 3. Composition of ewe milk by collection day.

	Treatment												
	C[a]						S[b]						
	19[c]	26[c]	33[c]	45[c]	54[c]	x̄	19[c]	26[c]	33[c]	45[c]	54[c]	x̄	SEM[d]
Milk, kg per 24 hours[e]	2.71	2.92	2.84	2.40	2.31	2.65	2.71	3.03	2.68	2.23	2.13	2.56	0.07
Component, %:													
DM[e]	19.5	19.7	20.5	21.6	22.2	20.7	20.7	19.5	20.9	22.5	24.2	21.6	0.17
Fat[f,g]	42.8	44.0	45.0	44.7	43.1[h]	44.0	44.8	43.3	45.9	46.3	46.3	45.3	0.36
Protein[e,g]	21.8	21.5	21.6	22.5[h]	24.9[h]	22.5[h]	20.0	21.9	20.8	20.8	22.9	21.3	0.25
Yield per 24 hours, kg:													
DM[i]	0.53	0.58	0.58	0.52	0.51	0.55	0.56	0.60	0.56	0.50	0.52	0.55	0.017
Fat	0.23	0.26	0.26	0.23	0.22	0.24	0.25	0.27	0.26	0.23	0.24	0.25	0.009
Protein	0.11	0.12	0.13	0.12	0.13	0.12	0.11	0.13	0.12	0.10	0.12	0.11	0.003

[a] C = control.
[b] S = CaSPO-supplemented.
[c] Collection day.
[d] SEM = standard error of mean.
[e] Linear (P < 0.01).
[f] Linear (P < 0.05).
[g] Percent of DM.
[h] C versus S (P < 0.10).
[i] Cubic (P < 0.10).

tion length, S yields were numerically equal to or greater than C at each collection date. Higher fresh milk and MF yields of fat-supplemented dairy cows have been reported, but MF percentages often remain constant (Coppock and Wilks, 1991; Canale et al., 1990; Robb and Chapula, 1987). An exception to this was found when Mattias et al. (1982) fed fat to lower-producing cows and the resulting increase in MF% caused higher MF production without changing MP. Similarly, in both lactating goats (Teh et al., 1994) and ewes (Hernandez et al., 1986), supplementation with CaSPO increased MF% and daily MF production, although MP was not increased. Furthermore, in experiments which employ shorter periods for adjustment to dietary fat and subsequent milk sample collection (10 to 20 days), MP is seldom increased, whereas increases in MF% are often found (Schauff and Clark, 1992; Storry et al., 1968). This difference suggests genetic potential for milk yield and time allowed for dietary adaptation may influence the effect of CaSPO on lactational performance.

In contrast to DM and MF%, MPR% was lower ($P < 0.10$) in the S treatment on days 42 and 54 postpartum (Table 3). Yield of MPR by S ewes also tended to be lower. When fat is supplemented to dairy cows, MPR content is often decreased, whereas MPR yields may (Kim et al., 1991; Downer et al., 1987; Palmquist and Moser, 1981) or may not (Kincaid and Cronrath, 1993; Canale et al., 1990) be decreased. Hoffman et al. (1991) concluded that MPR content was negatively correlated with fresh milk yields during fat supplementation. Both ruminal and mammary gland effects have been implicated for this tendency (Palmquist et al., 1993b; DePeters and Cant, 1992; Kim et al., 1991). Although differences were found for MPR% between C and S in the present experiment, 24-hour MPR yields were not different. Because C and S diets were high quality, the levels of microbial protein synthesis and dietary protein bypassing the rumen must have been adequate to maintain equivalent MPR synthesis in the mammary gland. Both MPR% and MPR yield increased linearly ($P < 0.01$) during lactation for C and S treatments.

Table 4 depicts the efficiency of 24-hour fresh milk, DM, MF and MPR production per daily ewe DMI. No differences were found between treatments, but efficiency of MP, DM and MF production decreased linearly ($P < 0.01$) for C and S ewes as lactation progressed. Efficiency of MPR production also decreased linearly ($P < 0.05$) as lactation progressed. Equal performance between treatments could be expected because both diets were considered high quality and contained N and energy components necessary for maximum MP (NRC, 1985). Although incorporation of 4.1% CaSPO into the S diet tended to alter DM and MF variables in late lactation, the substrate-sparing effect caused by the dietary provision of preformed FA for direct incorporation into MF was evidently not large enough or did not occur soon enough to significantly affect the overall synthesis of milk or milk components (Chilliard, 1993).

Lamb ADG for each measurement period is presented in Figure 2. Gains of twin lambs are combined so they can be expressed on a ewe basis. Gain decreased linearly ($P < 0.01$) as lactation length increased. In each weigh period, C and S lambs responded similarly; therefore, lamb ADG and total lamb gain per ewe for the complete experimental period were similar (Table 5). Neither lamb 60-day adjusted WW nor efficiency of lamb gain was different between C and S treatments. Lamb gain per daily ewe DMI decreased linearly ($P < 0.01$) across treatments from days 19 to 54 because ewe intakes were similar (Table 2).

Preweaning weight gain of lambs is directly influenced by ewe MP (Metcalf and Weekes, 1990; Torres-Hernandez and Hohenboken, 1980). While breeding and nutritional programs are both means by which MP and composition can be altered, dietary manipulation causes the fastest changes (Sutton, 1989). Metcalf and Weekes (1990) reported heavier

Table 4. Efficiency of milk production by collection day.

	Treatment												
	C[a]						S[b]						
	19[c]	26[c]	33[c]	45[c]	54[c]	x̄	19[c]	26[c]	33[c]	45[c]	54[c]	x̄	SEM[d]
24-hour yield per daily ewe DMI, kg per kg:													
Milk[e]	1.23	1.13	1.09	0.90	0.89	1.05	1.26	1.16	1.04	0.86	0.82	1.03	0.03
DM[e]	0.24	0.22	0.22	0.19	0.20	0.22	0.26	0.23	0.22	0.19	0.20	0.22	0.06
Fat[e]	0.11	0.10	0.10	0.09	0.09	0.10	0.12	0.10	0.10	0.09	0.10	0.10	0.03
Protein[f]	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.01

[a] C = control
[b] S = CaSPO-supplemented.
[c] Collection day.
[d] SEM = standard error of mean.
[e] Linear ($P < 0.01$).
[e] Linear ($P < 0.05$).

weaning weights in lambs that nursed ewes having adequate energy intakes as opposed to those reared by ewes in an energy-deficient status. However, Torres-Hernandez and Hohenboken (1980) concluded increasing lamb weights through increases in ewe MP may not be economical. In regressing ewe MP on preweaning lamb gains, these researchers reported 9.1 and 14.3 additional liters of milk would be needed for each additional kilogram of weight gain in single and twin lambs, respectively.

On the other hand, changes in milk composition may elicit the larger response in lamb performance. Lynch et al. (1991) were successful in increasing levels of methionine and lysine in the milk of ewes supplemented with these rumen-protected amino acids, which increased lamb daily intake of each enough to increase gains. Hernandez et al. (1986) found increased MF content and yields when ewes were supplemented with CaSPO. In a subsequent study, twin lambs of CaSPO-supplemented ewes were one kilogram heavier by five weeks of age than twins of non-supplemented ewes. Unlike the present experiment, diets fed by Hernandez et al. (1986) were deficient in energy needed for maximum milk production and supplementation began at parturition. Furthermore, the lambs in the Hernandez et al. (1986) study were creep fed, whereas those used in the present study were not allowed access to creep feed. The results of the present experiment suggest that CaSPO supplementation does not improve ewe lactational performance enough to influence lamb performance when high quality diets are fed and lambs are not creep fed.

Conclusions

Incorporation of the calcium salts of palm oil fatty acids into alfalfa-based lactation diets may alter subsequent ewe milk composition. However, beginning lipid supplementation of high quality diets 15 days postpartum does not allow this ingredient enough time to cause compositional changes great enough to affect either ewe lactational performance or lamb gains to 54 days of age. Supplementation of lower quality diets during late gestation through parturition and lactation might ultimately affect pre-weaning lamb growth economically.

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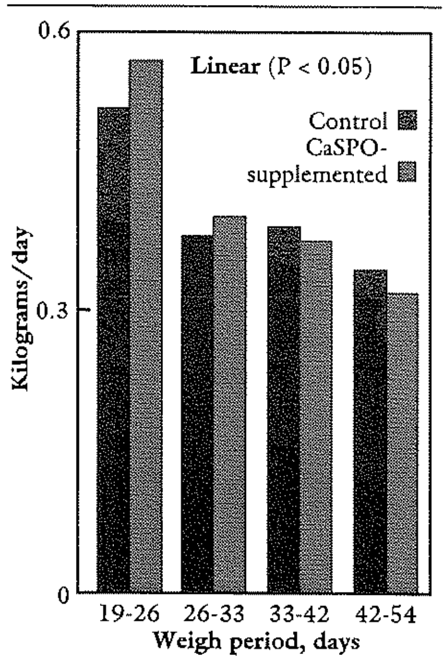
Table 5. Lamb performance from day 19 to 54 of lactation.

	Treatment		
Item	C[a]	S[b]	SEM[c]
Lamb ADG/ewe, kg/day	0.40	0.40	0.04
Total lamb gain/ewe, kg[d]	13.99	14.05	0.31
Lamb 60-day adjusted WW/ewe, kg[e]	39.60	39.80	0.01
Lamb ADG/daily ewe DMI, kg/kg	0.15	0.15	0.01

[a] C = control.
[b] S = CaSPO-supplemented.
[c] SEM = standard error of mean.
[d] Values are combined twin performance per ewe.
[e] Adjusted for type of birth, sex, lamb age and ewe age.

Figure 2. Combined daily gain by period of twin lambs nursing ewes fed control and CaSPO-supplemented diets (per ewe).



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Genetic Alternatives Addressing the Economic Impact of Changes in Public Lands Grazing Policy and Loss of the Wool Incentive Program on Intermountain Range Sheep Production Systems

A.D. Knight[1] and G.D. Snowder[1,2]

Summary

Intermountain range sheep production systems were evaluated to assess the combined economic impact of raising the public lands grazing fee from $1.87 to $3.96 per animal unit month (AUM) and loss of the wool incentive program. Results demonstrate a formidable economic shortfall for conventional western range breed and management systems and emphasize the importance of adopting alternative breeding and management approaches if economic viability is to be retained. Loss of wool incentive payment revenue shifts production emphasis increasingly from wool to more weight of lamb weaned. For the $0.57 lamb and $0.72 wool prices used in the 1992 production year "composite" Rambouillet flock example, a 31% increase in lamb price or a 247% increase in wool price would be needed to recoup the base economic returns to cash operating costs that were realized with the current AUM grazing fee and the wool incentive payment program in place. The economic shortfall can also be reduced by breeding ewes with genetic potential for early sexual maturity and high prolificacy. The Finn × Rambouillet cross flock reduced the live lamb price needed to recoup the base by about $0.10 per pound compared to a straightbred Rambouillet flock. Sheep producers are encouraged to shift to an earlier sexually maturing and more prolific breed of sheep by crossing their typical western range white-faced ewes to rams from prolific breeds such as the Finnish Landrace. However, it is estimated that approximately six years are required for sheep producers to make this shift in the genotypes of their current breeding stock while the Wool Incentive Act is to be phased out in a three-year period.

Key words: sheep, economics, lamb, wool, reproduction, grazing.

Introduction

Legislative actions and proposals by the 1994 Congress are to have an impact upon the economic stability of a large proportion of U.S. sheep producers, especially range sheep producers. The degree of impact on sheep producers is yet to be realized. Range sheep producers in the intermountain western United States are generally dependent upon pnblic lands for livestock grazing. Funding of the incentive payment provisions of the National Wool Act of 1954 is to be phased out over the three-year period of 1994 to 1996. Proposed changes in livestock grazing fees on public lands could raise current fees from $1.87 AUM to $3.96 AUM (Department of Agriculture, 1994). Increased grazing fees accompanied by the phase-out of the wool incentive payment will generally decrease the income revenues for sheep producers, especially those producing fine wool sheep on public land. This loss of revenues may be recovered by reduction of input costs, which are mostly fixed, and/or increasing productivity of the sheep flock. Increasing productivity occurs by improved management, by improved genetic merit or by a combination of management and genetics. The purpose of this study was to evaluate genetic alternatives to improve productivity and offer an assessment of research findings that may be useful to the industry in responding to consequences of recent and proposed public policy changes.

Materials and Methods

An investigation of the economic impact of the National Wool Act of 1954 was conducted to assess the

[1] USDA-ARS, U.S. Sheep Experiment Station, Dubois, ID 83423.

[2] Contact author: USDA-ARS, USSES, HC-62, Box 2010, Dubois, ID 83423; phone (208) 374-5306, fax (208) 374-5582.

degree of economic importance of the wool incentive to American sheep producers from 1954 to 1993. Significant increases in the wool incentive payment did not occur until after 1976. From 1977 to 1992, the support price increased from $0.72 to $1.97. The economic influence of the wool incentive payment is defined as the percent of total income revenues from sheep production systems for the years 1977 through 1992. Prices for lamb and wool were compared from 1977 to 1992 by adjusting dollars to the product price index. Trends in real dollar values for lamb and wool are estimated by regressing prices on year. Dependency or "risk" on the wool incentive payment is derived by regressing the deviation between the wool incentive support price and the national average wool price and lamb price on years.

A computer program was used to inter-relate economic and production parameters of range sheep systems. Wool and lamb components of production systems using contrasting germplasm resources were evaluated using varying economic parameters under similar management systems. "Composite" flocks of two different genotypes were developed as representative of two contrasting inter-mountain shed lambing operations: 1) a conventional system using Rambouillet (fine wool type) ewes where replacement ewes are raised, sheared as yearlings, but bred to first lamb at two years; and 2) a Finncross ewe (prolific breed type) system using Finnsheep × Rambouillet type ewes, a logical extension from the first system to increase lamb production. Information inputs for the two production systems were obtained from established shed-lambing commercial operations and from the USDA-ARS, U.S. Sheep Experiment Station and other ARS location research reports. After supplying necessary inputs for the computer program, "what if" scenarios were computed to determine effects of higher grazing fees and lost wool incentive payment revenue so that implications could be drawn as to production and economic consequences.

Parameterization of the sheep flocks was based upon data from a 12-year study comparing purebred flocks, including Rambouillets and Finncross ewes (Ercanbrack and Knight, 1989), and from data collected from commercial range sheep production systems. The composite flocks were made up of breeding ewes at ages distributed from one year through maturity for which an approximate annual replacement rate of 20% of the mature ewes (two years old and older) would maintain stable numbers. Each flock consisted of a total of 4,800 ewes, of which 800 were replacement yearling ewes. Suffolk rams were bred to the majority of the ewes in each flock for terminal market lamb production. Each flock produced their own replacement animals by breeding approximately 1,300 "superior" ewes to selected sires of the same genotype. The Finncross flock was assumed to be a genetically stable population having descended from *inter se* matings of F1 animals; consequently, there was no need to maintain purebred Rambouillet ewes within the Finncross flock to produce F1 Finn × Rambouillet ewes.

All costs are expressed on a "ewes into breeding" basis. The average number of lambs weaned per ewe into breeding is referred to as the "net rate." Producers often use expressions similar to net rate based on lambs born to ewes lambing or lambs turned out with ewes onto grass shortly after lambing, which are, of course, somewhat higher than net rate or lambs weaned per ewe exposed at breeding. The net rates for Rambouillets and Finncross ewes were 1.38 and 1.49, respectively. Net rate was based on the product of ewe viability (breeding to lambing), fertility, prolificacy, lambs born live and lamb survival to weaning.

Finn × Rambouillet ewes were exposed to rams at approximately eight months old while Rambouillet ewes were not exposed to rams until about two years of age. This is a current and common management practice that is often confounded with breed type in western states production systems. The higher fertility and prolificacy of Finn × Rambouillet yearling ewes (93% and 154%, respectively) compared to Rambouillet yearling ewes (typically with a yearling ewe fertility of 25% and a prolificacy mean of 110%; unpublished data, U.S. Sheep Experiment Station) is the justification for this breed difference in management of young ewes (Dickerson, 1977; Ercanbrack and Knight, 1985). Although fertility of Rambouillet yearlings can be improved by selection and additional cost inputs such as from improved management to increase body weight into breeding (Westman et al., 1993), it becomes speculative under range production systems as to whether these additional input costs can be recovered by increased revenues.

Wool production levels were based upon production averages of 12 years of research (Ercanbrack and Knight, 1989). Grease fleece weight averaged 9.9 and 7.9 pounds for Rambouillet and Finn × Rambouillet ewes, respectively. Fleece quality was determined at shearing as a visual estimate of spinning count grade. The average spinning count grades for Rambouillet and Finn × Rambouillet ewes were 64s and 60s, respectively. Wool price for the finer fleeced Rambouillet was based on 1992 average prices and set at $0.76 per pound grease weight. The wool price for Finn × Rambouillet ewes was based on an adjustment of the Rambouillet average price paid for wools of various spinning counts from 1978 through 1988 (ASPC, 1988). Thus, the Finncross wool, because of its coarser grade and greater variation in fiber diameter, was discounted by 25% compared to the wool of purebreds (Ercanbrack and Knight, 1989) and set at $0.57 per pound grease weight. A previous study has also reported a similar reduction in the fleece quality of Finncross ewes (Drummond et al., 1982).

Lambs were weaned and marketed off the mountain range at approximately 185 days of age. Weaning rate for the Finncross system is modest and assumes some fostering but no orphan lambs raised. Values for lamb loss from birth to marketing were assumed at 0.146 lambs per ewe for the conventional system and 0.192 for the

Finncross system. Average lamb weaning weight for the Finncross system is 104 pounds; 4 pounds less than lambs from the conventional system (Dickerson, 1977; U.S. Sheep Experiment Station, unpublished data). Lamb price is the average 1992 market value for fall-weaned lambs, $0.57 per pound live weight. No price difference due to genetic type exists between Suffolk sired lambs from Rambouillet or Finn × Rambouillet ewes.

Production components inter-related by the computer analyses include flock size, lamb and wool production levels, harvested feed and grazing costs, feed amounts used during different stages of the production cycle, other production cash costs and units of production and their unit value. The management systems for both flocks are similar and common to herded range sheep operations in the intermountain west. Ewes are shed-lambed in early spring, turned out on grass pasture or range after lambing, grazed on public lands in the foothills and mountains during spring and summer, and bred on field aftermath or pasture in the late fall. Ewes spend the winter on desert sagebrush range and are then gathered for lambing in confinement of a drylot. Public lands are grazed for 248 days annually; pasture, field aftermath and dry lot feeding make up the balance of the year. Table 1 summarizes cash costs (feed, labor, etc.) associated with each sheep production system. Fair market value of all home-grown hay and grain is used as harvested feed costs. All costs are typical for 1992 which was a year of low lamb prices and modest wool prices that followed several years of relatively stable total sheep numbers and moderate increases in the incentive payment level. Similar production costs and per-ewe returns were reported for Idaho shed-lambing operations by Rimbey and Oltjen (1994). Production costs (feed, labor, etc.) of the Finncross system increase commensurate with the higher level of lamb production and equate to a 10.4% increase in total cash costs. Economic analyses include income generated and the cash cost expenses incurred in the generation of that income.

Table 1. Actual and "what if"[a] outcomes for two composite intermountain range sheep shed lambing production systems.

Item	Production system: Conventional[b]	Finncross[c]
Current (1992) AUM grazing fee, full wool incentive payment:		
Mature breeding ewes, count	4,000	4,000
Yearlings, no.	800 (not bred)	800 (bred)
Net rate[d]	1.38	1.49
Lamb weight, pounds	108	104
Lamb price, $/pound	0.57	0.57
Wool weight, pounds	9.89	7.86
Wool price, $/pound	0.76	0.57
Feed cost per ewe bred, $[e]	36.53	32.84
Labor costs per ewe bred, $[e]	21.57	20.67
"Other" costs per ewe bred, $[e]	26.10	23.93
Return above cash costs, $	80,000.00	99,368.00
Return per ewe bred, $	20.00	20.70
AUM grazing fee at $3.96, full wool incentive payment:		
Return per ewe bred, $	17.38	17.99
Net Rate to recoup base[f]	1.42	1.47
Lamb price to recoup base, $/pound	0.59	0.56
Wool price to recoup base, $/pound	0.84	0.51
AUM grazing fee at $3.96, no wool incentive payment:		
Return per ewe bred, $	-2.19	4.98
Net Rate to recoup base	1.76	1.70
Lamb price to recoup base, $/pound	0.75	0.65
Wool price to recoup base, $/pound	2.64	2.05

a Outcomes based on changes in actual production and/or cost inputs.
b Rambouillet ewes, replacements first bred to lamb as two-year-olds.
c 1/2-Finn × Rambouillet cross ewes, replacements first bred to lamb as yearlings.
d Net rate = average number of lambs weaned per ewe exposed at breeding.
e Conventional system per ewe into breeding costs are higher but total costs (total ewes × per ewe into breeding cost) are lower than the Finncross system.
f Base is the $80,000 above cash costs generated by the conventional system and regarded as the minimum return necessary to maintain economic viability.

Because the resulting economic position in ability to meet debt commitments vary among operations, cash operating costs do not include individual operator debt structure, living allowance or imputed capital returns. All of these excluded costs must be covered by the return to cash operating costs or, if not paid, result in creation of additional debt. Included cash costs are all components of the Standardized Performance Analysis (SPA) calculation of "total operating costs per breeding ewe" with the exclusion of real property and income taxes, depreciation, insurance other than that applied directly to the sheep operation, principal and interest on debt and family living withdrawals (American Sheep Industry Association Producer Education and Research Council, 1994.)

Two economic scenarios are compared with the 1992 actual production costs and returns. The first situation is that of the effect of increasing public grazing fees from $1.87 per AUM to the proposed $3.96 per AUM (Department of Agriculture, 1994) on revenues received above cash costs. The second analyses looks at the effect of increasing public grazing fees to $3.96 per AUM and elimination of wool incentive payments. The minimal economic position is defined as the money received from the sale of lambs and wool plus the wool incentive payment for the actual conventional Rambouillet system after recovery of cash operating costs with grazing fees at $1.87 per AUM.

Because 1992 was a year of low lamb prices and modest wool prices, the monies received above cash operating costs for the conventional Rambouillet system is assumed to be the financial base that must be regained for economic viability after increasing the AUM grazing fee and eliminating the wool incentive program. "Needed to recoup base" figures are calculated and represent the increase in production or increase in price to recover returns above cash costs equal to the actual return of the conventional system. Only single sources of income (lamb or wool) are considered in the needed to recoup base figures.

Grazing fees were only analyzed at two base figures, the current fee of $1.87 per AUM and the proposed fee of $3.96 per AUM. It is our opinion that the proposed fee which is still subject to open debate and Congressional approval will be reduced, but at present there is no other fee that has been presented for public consideration. Although other federal and public organizations have identified different grazing fee levels, it was not our objective to determine an optimum grazing fee, but rather to consider the worst case scenario ($3.96 per AUM) compared to the present situation and to evaluate the production potential of various genotypes to offset increased grazing fees and loss of the Wool Incentive Program.

Simulations varying economic input cost parameters such as feed, management or other production costs were not attempted because the objective was to evaluate only genetic alternatives to address the economic impact of proposed changes in public policy. Therefore contemporary input costs were derived without consideration of possible management alternatives to reduce their costs. Producers are advised to be ever vigilant of practical approaches to reduce their input costs.

Results and Discussion

The National Wool Act of 1954

In December of 1953 the Department of Agriculture suggested to then-President Dwight Eisenhower that an "incentive payment" to domestic wool growers might be used as an approach to achieving a sound domestic sheep industry. The act was approved in 1954 and was introduced "as a measure of national security and in promotion of the general economic welfare, to encourage the annual domestic production of approximately 300 million pounds of shorn wool, grease basis, at prices fair to both producers and consumers in a manner which shall have the least adverse effect upon foreign trade" (National Wool Act, 1954). The law established funding for the program from a percentage of wool tariffs, not by taxes to the American people. The Wool Incentive Act never did achieve the production of 300 million pounds of wool nor did it prevent the precipitous decline in sheep numbers that commenced in 1960 (Figure 1).

Although there were many variables involved, the early years of the program may not have created sufficient financial incentive to encourage maintaining or increasing sheep numbers. During the first 11 years (1955 to 1965) of the program, the incentive level remained at $0.62. This was followed by five years (1966 to 1970) of modest increases and then six years during the Nixon Administration (1971 to 1976) when the payment level was "frozen" at $0.72. In 1977, at the urging of sheep producer organizations, the freeze was removed. By this action the USDA parity index as related to agricultural production costs was again used in determining the incentive payment level. During the next 16-year period (1977 to 1992) of relatively rapid increases in the annual incentive payment rate (and rapidly increasing production costs), total sheep numbers continued to trend downward, but at a slower rate. This slower trend gave way to another dramatic decline during 1993 when total numbers dropped to 9.08 million head.

Changes in lamb and wool prices and dependency on the wool incentive payment were identified by regression analyses. Wool and lamb prices were adjusted to real dollar value using 1977 as the base year. The R^2 values from regressing adjusted wool and lamb prices on year were low and not significant (0.04 and 0.19, respectively), indicating that average wool and lamb prices did not increase from 1977 to 1992. Further, there were strong linear associations with the differences between the incentive payment rate and the average lamb price ($0.07 per pound per year; $P < 0.001$) and for wool ($0.08 per pound per year; $P < 0.01$) when regressed on years. This widening economic gap between the incentive payment rate and the price received for lamb and wool implies an ever increasing economic reliance of the industry on the wool incentive payment.

Accompanying the upward trend in incentive payments from 1977 to 1993, an additional cost to range operations came in the form of increases in the AUM fees for grazing on public lands. When the incentive program was begun (1954), the AUM charge was $0.15. Fees have varied for Bureau of Land Management (BLM) and National Forest grazing in the interim but have gradually increased to the current uniform fee of $1.87 per AUM in 1992. When the AUM grazing costs (based on time spent on public grazing lands) and the incentive payment (based on pounds of shorn wool and pounds of lamb marketed) are compared, the benefits of the incentive payment have outweighed the increasing AUM costs with a positive economic counterbalancing effect.

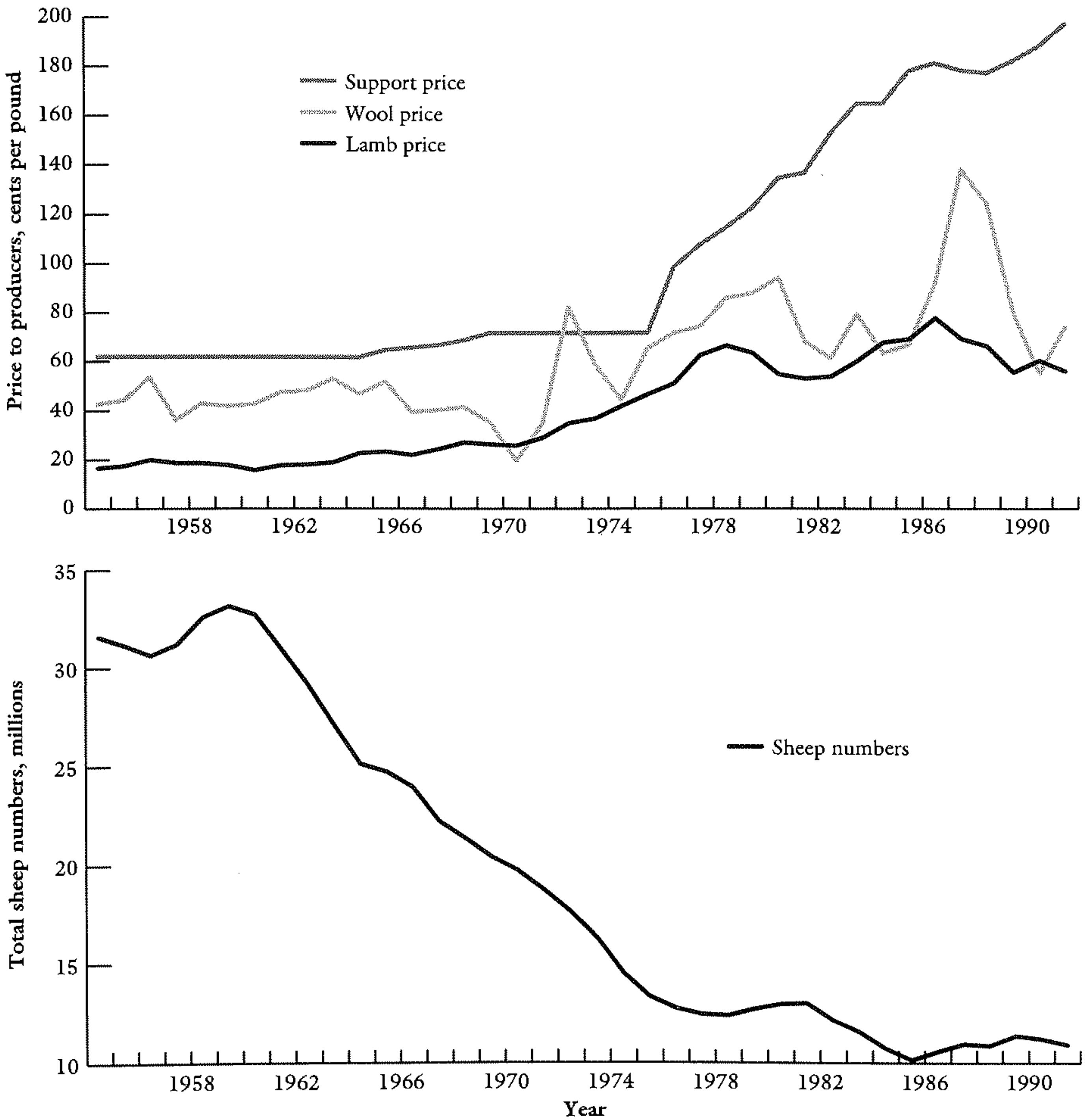
Current Economic Scenario

Results of the economic analyses are summarized by flock and economic scenarios in Table 1. The first column represents the conventional range operation with Rambouillet ewes and the second column represents the production system with Finn × Rambouillet cross ewes. The table is divided into three sections representing different economic scenarios: 1) the 1992 actual economics; 2) the 1992 situation imposed with increased grazing fees; and 3) the 1992 situation with increased grazing costs and the loss of the wool incentive. The conventional system, represented by a

Rambouillet-type flock, generates $80,000 total above cash operating costs. The $80,000 figure is the base point that must be regained for economic viability after imposing increased AUM grazing fees and elimination of the wool incentive program. The "needed to recoup" base estimates represent the increase in production (net rate) or increase in price (lamb and/or wool) to recover returns above cash costs equal to the $80,000.

In the conventional system, all costs are carried by the 4,000 ewes put into breeding. Accordingly, wool production by the replacement ewes is credited to the ewes put into breeding. Thus the total return (lamb, wool, salvage sales) above cash costs for the

Figure 1. Changes in sheep numbers, incentive program price support, average wool price and average lamb price during the history of the wool incentive program.



conventional system is the $20 return per Rambouillet ewe times 4,000 ewes, or $80,000. Total return for the Finncross system ($99,368) is higher based upon the per-ewe return ($20.67) times 4,800 rather than the 4,000 of the conventional system. The higher total return is largely due to the higher reproductive performance of the Finncross ewe at all ages, but particularly as yearlings (Ercanbrack and Knight, 1985). The Finncross flock weaned 24.8% more total weight of lamb with an accompanying increase of 10.4% total cash costs when compared to the conventional system.

The fact that Finncross ewe lambs can be successfully bred is inherent to the Finncross production system and is generally not a viable option for other range breeds in the inter-mountain region. Also, the use of an earlier sexually maturing and prolific breed of sheep has two other advantages that should be noted. One, because the operation uses public lands, the range allotment (number of head) could be a limiting factor in determining an operation's total number of ewes; a yearling Finncross ewe with a lamb is counted onto the allotment as one animal, the same as the yearling Rambouillet ewe that does not have a lamb. It would, therefore, be more efficient usage of the allotment to run the Finncross ewes. Two, ewe lambs of common western range breeds can be and sometimes are bred, but additional cost inputs (feed and/or other treatments) are most generally required to achieve even modest levels of reproductive performance; and, many producers do not believe there is sufficient payback to offset ewe lambs. On the other hand, very high reproductive performance of Finncross ewe lambs is achieved with little or no additional cost inputs.

Grazing Fee and Incentive Payment Considerations

The increased grazing fee scenario applied to the conventional system results in a decrease of $10,480 or 15.1% fewer dollars available to cover all cash and other costs associated with the operation. This is a significant increase in expense for an industry with net profits at about 2.5%. These results may infer that the proposed increase in AUM grazing fees is too high for the conventional sheep operations when considered with a statement within the proposal that says that "the fee charged should not cause unreasonable impacts on livestock operations that are heavily dependent on public forage" (Department of Agriculture, 1994). For the production system to recoup the loss without any improvements in management or genetic productivity, lamb or wool prices will have to increase $0.02 or $0.08 per pound, respectively. Dependence upon increases in the market price increases the "risk." Therefore with increased grazing fee costs producers will need to consider alternatives under their control, such as management, genetic improvement and marketing.

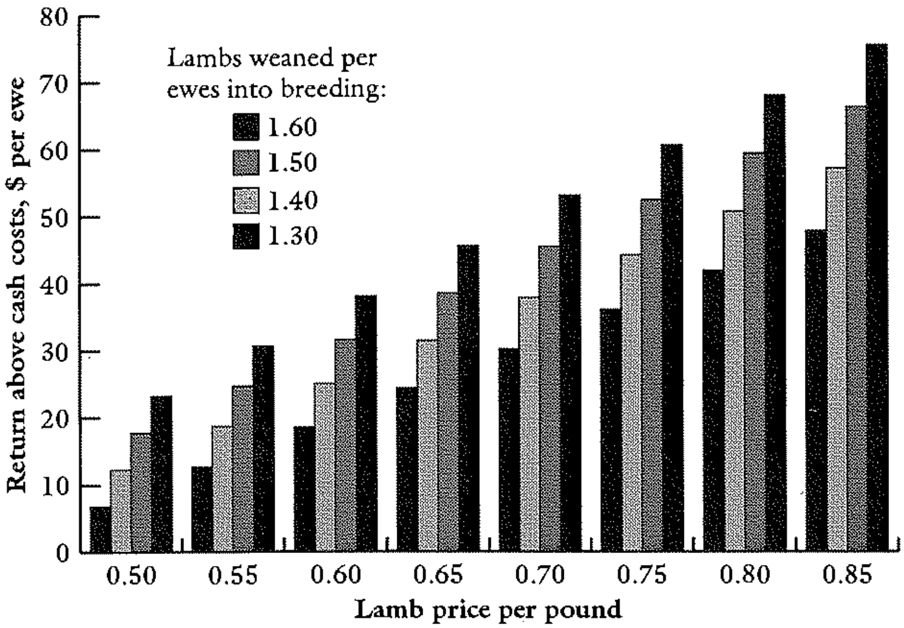
In comparison, increasing the grazing fee reduced the total return to the Finncross system to $86,352 ($17.99 return per ewe × 4,800 ewes), about 8% above the base $80,000 amount. Assuming that $86,352 is sufficient to meet the above-cash costs of the sheep enterprise, results of increased grazing fee costs will leave the Finncross system in a better financial position than the conventional Rambouillet system.

One management alternative that may be made available to federal land grazing permittees according to the proposed rules is "an incentive-based grazing fee" that, upon demonstrated compliance with special rangeland improvement criteria, would make a permittee eligible for a "30% reduction in the grazing fee." The criteria for evaluation of a grazing permit for range improvement are yet to be established. However, scientific studies indicate that sheep, when properly managed, can be a key component in sustainable agriculture in the production of food and fiber on private and public grazing lands (Ely, 1994; Glimp and Sherman, 1994; Havstad, 1994; Olson and Lacey, 1994; Taylor, 1994). The financial incentive to improve public lands is well meaning and could reduce grazing expenses by $3,144 in the conventional system. The economic advantage of this financial incentive could easily be lost if additional costs (reduced stocking rates, increased fencing, increased management, etc.) are associated with achieving the incentive-based fee. The incentive clause places much of the responsibility and financial costs for public rangeland improvement upon the grazing permittee; yet improvements in public grazing lands extend to the wildlife habitat, watershed function, recreation and other uses as well (Glimp and Swanson, 1994; Mosley, 1994). For this reason, the incentive clause has been viewed as punitive by some permit payees under whose stewardship the general condition of public rangeland has been characterized as "better today than it has been at any other time this century" (Department of Agriculture, 1994).

Solutions to recouping the financial base include management and genetic approaches to improving lamb production. This may include increasing reproductive rates, lamb survival, lamb growth and so forth. Figure 2 clearly illustrates that there has been enormous economic motivation to improve profits by increasing lamb production. At a lamb price of $0.65 per pound, an increase of just 0.1 lamb per ewe from 1.40 to 1.50 "lambs weaned" would increase the return per breeding ewe above-cash costs in the conventional system from about $31 to $39 (price of wool unchanged and other per-ewe costs commensurate with the increased level of production).

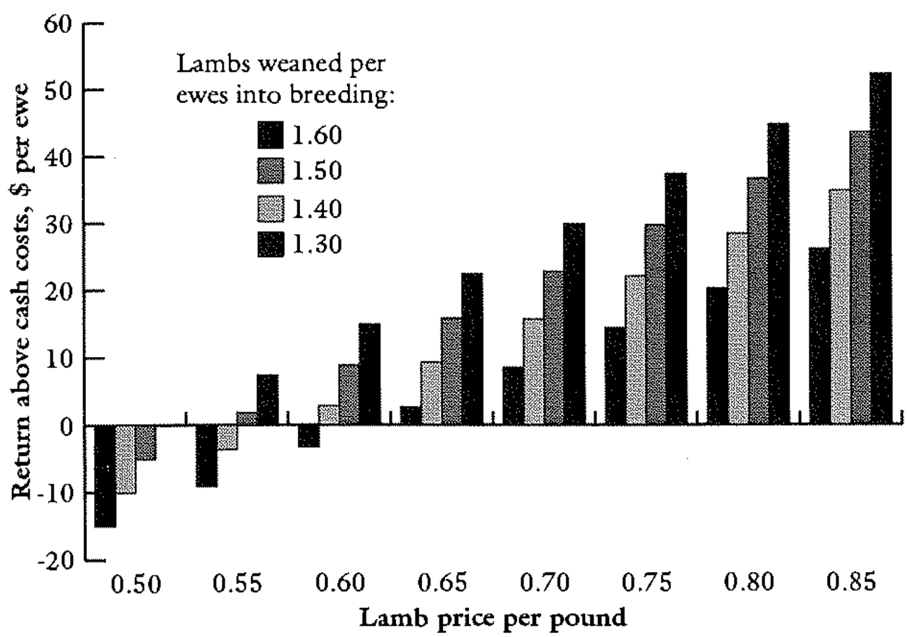
The scenario of the three-year phase-out of the wool incentive program and increased grazing fees creates a need for higher lamb prices and/or further increases in lamb production (Figure 3). Again using 1.40 lambs weaned, even the $20 return per ewe level for the conventional system is not realized until the lamb price reaches about $0.73 per pound. Of course, an improvement in the wool market can alter this outcome, but the increase in wool prices must be substantial. From the conventional system values in Table 1 it can be determined that to recoup the $80,000 base return, lamb price must increase 31%, which is in great

Figure 2. The influence of varying live lamb price and number of lambs weaned per ewe on the economic returns above fixed cash costs of a conventional western range white-faced sheep production system under actual 1992 input costs.[a]



[a] The public land grazing fee was $1.87/AUM and the Wool Incentive Program was fully funded.

Figure 3. The influence of varying live lamb price and number of lambs weaned per ewe on the per ewe economic return basis above fixed cash costs of a western range sheep production system under actual 1992 input costs.[a]



[a] Without the wool incentive payment and an increased public land grazing fee ($3.96/AUM).

contrast to the necessary 247% increase in wool price.

While there is no real mathematical "solution" intended for this kind of production analysis, the "what if" scenario approach does illustrate some of the dynamics of the economic and biological variables involved. For example, the base return can be recouped in the Finncross scenario by the wool price ($0.57 per pound) and a $0.66 per pound lamb price (Table 1). At a $0.66 per pound lamb price, what would the conventional system have to realize in wool price to reach the same base? This outcome is illustrated in Figure 4. At a lambs-weaned rate of 1.40, even with a $1.60 wool price the return above cash costs remains slightly below the desired $20 per ewe minimum. Although economic forces that may affect lamb and wool prices following phase-out of the wool incentive program cannot be reliably predicted, the evidence certainly points to the real need for gains in reproductive performance.

Merely recouping the financial loss associated with increased grazing fees and phase-out of the wool program will not stop the declining mode of the American sheep industry. Without sufficient economic incentive, the industry may be unable to attract enough young people to give the industry the robustness necessary to carry it into the 21st century. Clearly, production as usual is no longer a viable alternative. Nor is it likely that a solution will rest with any one alternative. There are, however, well-researched options that should be carefully evaluated.

One alternative is to use highly prolific crossbred ewes such as the Finnsheep or Booroola Merino. The most thoroughly evaluated crossbreeds in this country involve the Finnsheep, first imported in 1968. Extensive research studies under a wide variety of production conditions found that 1/4-Finn and 1/2-Finn ewes mated to good quality meat-type rams produce a prolific crop of crossbred lambs that are hardy, grow quickly and are of acceptable carcass quality (Boylan, et al., 1976; Thomas et al., 1976; Dahmen et al., 1979; Mendenhall and Ercanbrack, 1979;

Ercanbrack and Knight, 1985, 1989; Snowder et al., 1986; Ramdas et al., 1993). Viability (survival to weaning age) of lambs born to Finn and Finncross ewes has been reported as high, despite light birth weights and a high incidence of multiple births (Donald et al., 1968; Dickerson et al., 1975; Maijala and Osterberg, 1977; Oltenacu and Boylan, 1981; Ercanbrack and Knight, 1985). The reduction in fleece weight due to Finnsheep breeding is minimal. The average lifetime 1/4- and 1/2-Finncross fleece weights per ewe were 95% and 82%, respectively, as high as those of purebreds (Ercanbrack and Knight, 1985). This is a production compromise that becomes even less important with the loss of the incentive payment program.

Continually generating F1 Finncross ewes for replacements is accompanied by problems inherent in the production and distribution of cross-bred stock. However, comparison of concurrent groups of F1 Finnsheep crosses with *inter se* mated, advanced-generation crosses (F2s and greater) selected for pounds of lamb weaned showed that the two groups were equal in pounds of lamb weaned after 10 years (109.6 and 109.3 pounds for 1/2-Finncross F1 and *inter se* groups at 110 days of age, respectively; Ercanbrack and Knight, 1989). These results certainly suggest that Finncross types can be developed from which their own replacements can be selected.

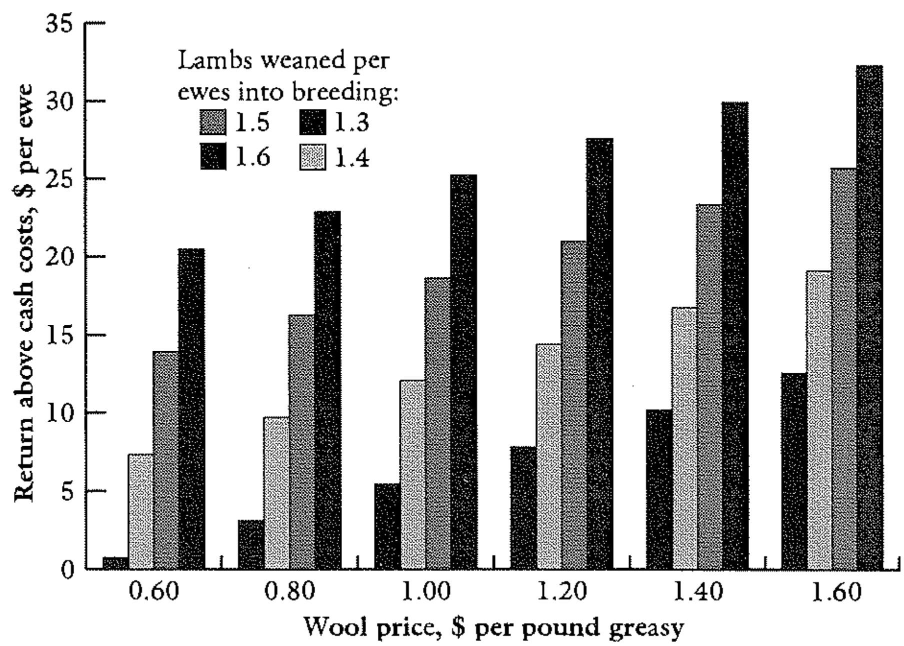
The Polypay breed, originally developed at the U.S. Sheep Experiment Station during the 1970s from a Rambouillet, Targhee, Dorset and Finnsheep foundation, was intended to fill the need for a range breed with a reproductive performance somewhat superior to contemporary adapted western range breeds (Hulet et al., 1984). Although the breed is widely used in farm flocks, it has never gained broad acceptance among range producers. Perhaps now is an appropriate time for re-evaluating the breed for use in range production operations.

Polypays at the U.S. Sheep Experiment Station have consistently weaned over 25% more weight of lamb under range conditions than other purebreds at the Station. Average mature ewe body size is only slightly less than that of Rambouillets and Targhees (162.6, 163.9 and 158.8 pounds for Rambouillets, Targhees and Polypays, respectively). Polypay ewe fleeces have averaged 8 pounds of 58s wool. Polypay lamb carcasses are comparable to those of other white-face breeds. In a recently completed study (Snowder et al., 1994), carcasses of purebred Polypay wethers were found to be similar to those of Rambouillets and Targhees in most respects, but even slightly superior in leg conformation and yield grade when compared at similar live slaughter weights. Polypay ewe lambs can be bred very successfully at seven to eight months of age.

The three-year phase-out of the incentive program does not afford producers the time needed to make a successful shift from a conventional to a highly prolific ewe type. When flock size is held constant, replacement of current breeding ewes with F1 crosses would typically accrue to a near maximum in about six years. All replacements coming into the flock would then be of the crossbred type and approximately 40% of such ewes would be in the peak production (four- through six-year-olds) age groups.

An additional option is to place continued emphasis on selection to improve litter weight weaned. While rapid increases in litter weight weaned can be realized quickly through crossbreeding with a prolific breed, with or without crossbreeding, selection should be continued to improve genetic expression of individuals within breeds and crosses. In a recently completed selection study that was continued over a 12-year period at the U.S. Sheep Experiment Station, four lines were selected solely for litter weight at weaning (120 days of age). The average weight weaned by these lines increased by more than 1.5 pounds per ewe per year over the period (Ercanbrack and Knight, 1994). Toward the end of the study, not only was progress still being made in litter weight, but progress was

Figure 4. The influence of varying grease wool price and number of lambs weaned per ewe on the per ewe economic returns above fixed cash costs of western range sheep production system under actual 1992 input costs at a set value of $0.65 for live lamb.[a]



[a] Without the wool incentive payment and an increased public land grazing fee ($3.96/AUM).

increasing at an accelerating rate in three of the four lines.

Conclusions

The phasing out of the Wool Incentive Program and accompanying increases in grazing fees will have a strong negative economic effect on fine wool sheep producers who graze on public lands. Some but probably not all of the economic shortfalls can be recouped by using ewes of greater genetic capacity for reproduction and by developing management systems to support higher reproductive and lamb survival rates. All of the lost revenue would be recouped by the Finncross system at a lamb price $0.10 per pound lower ($0.65 per pound) than that of the conventional system ($0.75 per pound). Wool production will continue to be a key enterprise component contributing about 10% of total enterprise revenues and should be given constant attention for improved quality; however, feeding and management strategies must avoid negative physiological relationships between wool and lamb that result in reduced lamb production. A three-year phase-out period of the Wool Incentive Payment is too short of a time period for producers to convert to a highly prolific breed type or to make sufficient genetic selection progress in lamb production to offset the loss of the wool incentive payment; no reasonable solution to this problem is offered.

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Dry Matter Intake of Freshly Harvested Wheat Forage and Supplemental Dry Matter[1]

W.A. Phillips[2] and D.L. VonTungeln[2]

Summary

Wether lambs were housed in individual pens and fed freshly harvested wheat forage daily to determine the effect of a daily allowance of 300 g of supplement supplied by either a high-energy (CORN) or low-energy (HAY) supplement on forage intake and total dry matter intake (TDMI). Fall/winter wheat forage was harvested fresh daily and fed for 28 days to 32 lambs in experiment 1. Lambs offered CORN or HAY supplements had greater ($P < 0.01$) TDMI during the first seven days of the experiment than lambs not offered any supplemental feed. Lambs offered CORN consumed the supplemental DM in place of wheat forage DM, while lambs offered HAY would consume wheat forage DM in place of HAY DM. In experiment 2, 33 lambs were fed freshly-harvested spring wheat forage daily for 14 days. Providing CORN or HAY supplements decreased ($P < 0.05$) forage intake, but supplementation had no effect ($P > 0.10$) on TDMI. In experiment 3, lambs ($n = 197$) grazing fall/winter wheat pastures were fed with either CORN or HAY for the first 10 days of the 70-day grazing period, but the amount of supplement fed was reduced by 10 percentage units each day. Lamb ADG was lower ($P < 0.05$) for supplemented groups than in non-supplemented groups. We concluded that feeder lambs presented with wheat forage for the first time need a 14-day adaptation period in the fall/winter and a seven-day adaptation period in the spring to reach maximum forage intake. Lambs will consume supplemental corn in place of wheat forage, but will consume wheat forage in place of supplemental hay. Providing supplemental DM to lambs grazing fresh wheat forage does not increase lamb performance.

Key words: wheat forage, corn, hay, voluntary intake, lambs, growth.

Introduction

Wheat forage is a high-quality forage and a major component of many forage livestock systems in the Southern Great Plains (Walker et al., 1988; Phillips et al., 1991). Wheat forage production occurs during two distinctly different phases, fall/winter and spring (Phillips, 1975). Fall/winter forage production is predominately leaf material and contains a high concentration of nitrogen (N) and a low concentration of neutral detergent fiber (NDF), acid detergent fiber (ADF) and dry matter (DM; Mader and Horn, 1986; McCann et al., 1991). In contrast, spring forage production contains more DM, less N and higher concentrations of NDF and ADF than fall/winter wheat forage (Phillips et al., 1995b). Although fall/winter forage is higher in quality than spring forage, animal performance from fall/winter forage is lower (Vogel, 1985; Phillips et al., 1991). Gallavan et al. (1989) hypothesized that the low DM content of wheat forage, especially fall/winter wheat forage, limits DM intake (DMI) and, as a result, animal performance. Although intracellular water in wheat forage can increase bulk, it has not been proven that high concentrations of intracellular water decreases DMI (Allison, 1985). It appears that animals not accustomed to grazing wheat forage have poorer performance during the first portion of the wheat-grazing period (Ford, 1984; Phillips, 1986). Mader et al. (1983) observed that steers consumed small quantities of low-quality forages while grazing winter wheat pastures, but ADG was not affected by supplementation strategy. Data on short-term supplementation of feeder lambs on wheat pastures is not available. Therefore the objectives of the following experiments were: 1) to determine the effect of a high-energy and low-energy DM supplement on DMI of fall/winter and spring wheat forage by feeder

[1] The authors thank Bill Jensen, Wesley Jackson and Nelson Reese for assistance in the care of the animals.

[2] USDA-ARS, Grazinglands Research Laboratory, P.O. Box 1199, El Reno, OK 73036.

lambs; and 2) to determine the effect of supplementation during the adaptation period to wheat pasture on feeder lamb performance.

Materials and Methods

Experiment 1

Thirty-two wether lambs (averaging 32 kg and five to six months old) were randomly assigned to one of three treatments to determine the effect of a high-energy or low-energy DM supplement on DM intake of lambs fed freshly harvested fall/winter forage. The treatments were: 1) wheat forage only (WF); 2) wheat forage plus 300 g of corn (CORN); and 3) wheat forage plus 300 g of hay (HAY). Lambs were housed in individual pens (0.7 m × 2 m) constructed of expanded metal in a non-climate-controlled barn and elevated 0.2 m above the floor. Each day, wheat forage was harvested between 0830 and 1000 hours with a flail harvester at a stubble height of 3.8 cm and transported in bulk to the feeding facilities. The wheat forage and supplement were fed in separate containers and lambs had ad libitum access to water and Ca-P-salt mineral mixture (27% dicalcium phosphate, 29% calcium sulfate, 32% salt, 7% magnesium oxide and 5% wet molasses). Each morning, forage and supplement not consumed the previous day were removed, weighed and sampled. The amount of wheat forage offered was adjusted daily based on the previous day's consumption so that the availability of wheat forage would not be limiting.

Wheat forage was harvested from a field established the previous September. Wheat was seeded with a no-till drill at a rate of 100 kg per hectacre and 90 kg of N per hectacre was applied. The CORN supplement was number 2 grade yellow corn and was ground through a hammer mill to break the kernel. The HAY supplement was Old World Bluestem grass hay [*Bothriochloa caucasica* (trin.) C.E. Hubb.] which had been ground through a 38-mm screen prior to feeding.

Wheat forage was sampled daily at feeding, dried at 65 °C for 72 hours in a forced air oven to determine DM content, composited weekly and analyzed for NDF, ADF and N content. Additional samples of fresh wheat forage were collected at feeding and immediately frozen for later determination of soluble and non-protein nitrogen. Wheat forage not consumed the previous day was removed from the feeder, weighed, sampled, dried at 65 °C for 72 hours in a forced-air oven, composited weekly across all animals and analyzed for N, NDF and ADF content. At each feeding, samples of supplements fed and not consumed the previous day were sampled, dried at 65 °C for 72 hours in a forced-air oven, composited weekly and analyzed for N, NDF and ADF content.

Analysis for N content in fed and refused forage and supplement samples was performed according to Association of Official Analytical Chemists (AOAC; 1975). The NDF and ADF content of the oven-dried wheat forage and supplements were determined using the procedure of Goering and Van Soest (1970). The N content of frozen fresh wheat forage was fractionated into insoluble and soluble N which was further fractionated into protein and non-protein N (NPN) as described by Phillips (1986).

Lambs were weighed at the beginning (November 8) and end (December 6) of the 28-day experiment following a 16-hour fast without feed and water. Statistical analyses were done using GLM procedure of SAS (1982) with animal as the experimental unit. Initial BW, final BW and changes in BW were analyzed using a model containing treatment as the only independent variable. Forage, supplement and total DMI were analyzed with a model containing treatment, period (week) and treatment × period as the independent of variables. When a significant treatment × period interaction was observed, the data were analyzed within each weekly period by the GLM procedures. Orthogonal contrasts were conducted to test the following effects: 1) no supplement versus supplement; and 2) CORN versus HAY. Chemical composition of the wheat forage was analyzed with period as the only source of variation. Differences among means were determined using the LSD procedure (SAS, 1982).

Experiment 2

Thirty-three wether feeder lambs (averaging 29 kg and five to six months of age) were randomly assigned to the same three treatments described in experiment 1 to determine the effect of DM supplementation on DM intake of spring wheat forage. This experiment was initiated on April 19 and terminated 14 days later. Feeding procedures, sampling, chemical analyses and statistical analysis were the same as described in experiment 1.

Experiment 3

One hundred and ninety-seven wether lambs (average weight of 29.7 kg and five to six months of age) were randomly divided into two groups (blocks) and within each group randomly assigned to one of three treatments: 1) grazed winter wheat pasture without any supplementation during the first 10 days (WF); 2) grazed winter wheat pasture and initially receiving 380 g of corn on day 1 of the grazing period, but the amount of corn decreased by 10% of the initial level each day so that on day 11 no corn was fed (CORN); and 3) grazed winter wheat pasture and initially receiving 600 g of hay with the amount of hay decreased by 10% of the initial level each day so that on day 11 no hay was fed (HAY). The amount of supplementation provided on day 1 was calculated to meet either 50% of the daily energy requirement (CORN) or 50% of the daily DM intake (HAY; NRC, 1985). Each treatment was randomly assigned to one of six pastures at a stocking rate of 13.5 lambs per hectacre. Lambs were weighed on days 0, 14, 28 and at the end of the experimental period (day 75). All body weights (BW) were taken following a 16-hour fast without feed and water. Lambs were kept in pens each night for predator control and to allow access to supplements. The CORN and HAY supplements fed in this experiment were the same as those used in experiments 1 and 2. Available forage was determined at the initiation of the grazing period by hand clipping all of the forage in a 0.25-m^2 area to ground level at two locations in each pasture. Clipped samples were dried at 65 °C for 72 hours in a forced-air oven to determine DM content. Pastures were used as the experimental unit and data were analyzed as a randomized complete block design using the ANOVA procedure of SAS (1982). Differences among means were determined by LSD procedures (SAS, 1982).

Results and Discussion

Experiment 1

Crude protein concentration in wheat forage averaged across the experimental period was 18.8% and was higher than CP concentration in corn (7.3%) or hay (5.4%) supplements. Average NDF and ADF concentrations in wheat forage were 47.1% and 25.9%, respectively, and were intermediate to that in the corn (22.4% and 2.3%) and hay (74.9% and 42.0%) supplements. Chemical composition of wheat forage was consistent across weekly periods, but DM content increased ($P < 0.10$) from 20.5% to 26.8% with time (Table 1).

In general, lambs fed corn or hay supplement consumed less wheat forage than lambs in the non-supplemented group, but total DM intake (TDMI) was similar ($P > 0.10$) among treatment groups with the exception of period 1 (Table 2). Lambs consumed greater ($P < 0.02$) amounts of corn supplement than hay supplement at each weekly period throughout the experiment and lambs in the HAY group consumed progressively smaller amounts of supplement DM with each weekly period. During period 1, consumption of wheat forage was similar ($P > 0.10$) among treatment groups, but TDMI was lower ($P < 0.02$) in the non-supplemented group than in the CORN and HAY groups. This was because these lambs consumed 270 and 212 g, respectively, of supplemental DM in addition to their wheat forage diets. By period 2, non-supplemented lambs had increased daily wheat forage DMI by 148 g per head or 25% over that observed in period 1. This increase

Table 1. Dry matter (DM) content and fractionation of nitrogen in wheat forage.

Item	Experiment 1					Experiment 2		
	Period 1	Period 2	Period 3	Period 4	SEM[a]	Period 1	Period 2	SEM[a]
DM	20.5[b]	20.8[b]	22.6[c]	26.8[d]	1.7	26.0	28.6	0.9
Total N[e], % DM	3.08	3.28	2.81	2.86	0.14	2.30	1.94	0.13
Soluble N, % total N	40.7	40.8	54.5	46.5	10.2	49.0	52.1	2.4
NPN[f], % total N	23.1	25.4	33.1	32.4	5.6	25.0	26.8	1.0
NPN, % soluble N	59.5	62.4	62.2	56.8	3.6	51.8	51.5	3.5

[a] SEM = standard error of the mean.
[b,c,d] Means for a given measurement within the same row without a common superscript differ ($P < 0.10$).
[e] N = nitrogen.
[f] NPN = non-protein nitrogen.

Table 2. Dry matter intake (DMI) of wheat forage, hay and corn supplements by feeder lambs.

Item	Treatment	Experiment 1				Experiment 2	
		Period 1	Period 2	Period 3	Period 4	Period 1	Period 2
Wheat forage intake, g/day	WF[a]	574	718	1,086[d]	1,059[d]	653[d]	1,089[d]
	CORN[b]	510	571	817[e]	777[e]	530[d,e]	880[e]
	HAY[c]	512	553	913[d,e]	977[d,e]	469[e]	966[d,e]
	SEM[f]	70.5	106.3	222.0	144.0	47	70
Supplemental intake, g/day	CORN[b]	270[d]	271[d]	268[d]	268[d]	208	221[d]
	HAY[c]	213[e]	200[e]	137[e]	69[e]	162	77[e]
	SEM[d]	11.9	27.8	40.7	28.1	10	14
Total DMI, g/day	WF[a]	574[e]	718	1,086	1,059	653	1,089
	CORN[b]	780[d]	842	1,085	1,045	738	1,101
	HAY[c]	725[d]	754	1,050	1,046	631	1,043
	SEM[f]	58.8	88.9	115.3	120.9	48	66

[a] WF = wheat forage only.
[b] CORN = wheat forage plus corn
[c] HAY = wheat forage plus hay.
[d,e] Means for a given measurement within the same column without a common superscript differ ($P < 0.05$).
[f] SEM = standard error of the mean.

was twice that observed for lambs in the supplemented groups. Consumption of NDF and ADF followed the same pattern as DMI. Lambs consumed more ($P < 0.01$) NDF during periods 3 and 4 than in periods 1 and 2, while lambs fed HAY consumed more ($P < 0.02$) NDF than lambs fed CORN or no supplement. It appears that during the first seven-day period of experiment 1, lambs had the capacity to consume more DM than that observed in the non-supplemented group. During this period, lambs consumed additional DM in the form of hay or corn to increase TDMI, but consumed more corn than hay. Lambs in the CORN group consumed all of the supplemental DM provided. Lambs in the HAY group progressively decreased hay intake while increasing wheat forage DMI to maintain TDMI equal to that observed in the other groups.

Initial and final BW of lambs were not different ($P > 0.10$) among the treatment groups (Table 3). Average daily gain for the 28-day period varied from none for the WF group to 49 g for the CORN group, but ADG was not different ($P > 0.10$) among treatments. Although lambs in the CORN group substituted corn DM for forage DM and should have been consuming more digestible DM than non-supplemented lambs, no differences in ADG were observed. Phillips et al. (1995b) has shown that feeding a high-energy supplement at 18% of the TDMI to lambs consuming fresh wheat forage can decrease wheat forage DM digestibility and, as a result, not increase total digestible DMI.

Experiment 2

Wheat forage fed in experiment 2 contained 2.2% N, which was a third lower than that observed in experiment 1 (Table 1). However, the proportions of N in the soluble and NPN forms were similar between the two experiments. Dry matter concentration was higher (27.3 vs. 22.7%) in wheat forage fed in experiment 2 as compared to experiment 1.

As observed in experiment 1, lambs offered either hay or corn supplemental DM had lower ($P < 0.04$) wheat forage DM intake than lambs in the non-supplemented group, but total DMI was not affected ($P > 0.10$) by supplementation (Table 2). Consumption of corn DM was consistent between periods and wheat forage DMI was reduced in equal amounts to accommodate for the consumption of corn. Lambs in the HAY group decreased ($P < 0.02$) hay intake with time and increased ($P < 0.01$) wheat forage DMI at the expense of hay DM. As observed in experiment 1, NDF intake was lower ($P < 0.02$) during the first period than during the second period and supplementation had no effect ($P > 0.10$) on NDF intake.

Lambs in experiment 2 were lighter than the lambs used in experiment 1 and ADG was negative for all treatment groups (Table 3). Observed ADG were lower than predicted based on energy and protein intake. However, the experiment was only 14 days long and differences in gastrointestinal tract fill would have had a greater impact on BW as opposed to a longer experimental period.

Experiment 3

Lambs fed supplements during the first 10 days on wheat pasture gained less ($P < 0.03$) weight than non-supplemented lambs and lambs fed hay gained less ($P < 0.03$) weight than lambs fed corn (Table 4). However, during the 10-day supplemental period, consumption of hay was greater and the consumption of corn was lower than observed in the previous experiments. The DM content of the wheat forage ranged from 20.8% to 33.0% during the grazing period. On average, pastures provide 33.3 kg of DM per lamb at the initiation of the experiment and did not limit the opportunity for lambs to meet the daily DM intake needs. Experiment 3 was conducted concurrently with experiment 1, so the N concentrations and distribution of N were similar to those reported for experiment 1. Animal performance during the first two 14-day periods were not ($P > 0.10$) affected by treatment (ADG = 115 g), but when accumulated across the experimental period, supplementation lowered ADG. Lower ADG in the supplemented groups may be due to supplementation during the first 10 days, possibly altering grazing behavior.

In situations where forage availability is not a constraint on DMI, long-term forage intake is primarily controlled by gastrointestinal capacity, which is sensitive to particulate digesta flow,

Table 3. Body weight (BW), average daily gain (ADG) and dry matter intake (DMI) of feeder lambs.

	Experiment 1				Experiment 2			
	Treatments				Treatments			
Item	WF[a]	CORN[b]	HAY[c]	SEM[d]	WF[a]	CORN[b]	HAY[c]	SEM[d]
Initial BW, kg	32.5	32.4	32.2	0.28	29.2	29.3	29.3	0.4
Final BW, kg	32.5	33.8	32.6	0.54	28.5	28.9	28.2	0.5
ADG, g	0	49	16	39	–48	–32	–76	32
DMI, g per $BW^{0.75}$	63.0	67.8	65.7	3.34	69.6	73.5	66.9	4.2

[a] WF = wheat forage only.
[b] CORN = wheat forage plus corn.
[c] HAY = wheat forage plus hay.
[d] SEM = standard error of the mean.

dietary concentration of undegradable fiber and rate of fiber breakdown (Allison, 1985; Bruckner and Hanna, 1990; Hyer et al., 1991). Short-term voluntary intake, as observed in experiment 1 and 2, was not limited by capacity, but by the willingness of the lamb to consume an unfamiliar forage. It appears that lambs need seven to 14 days to adapt to wheat forage, which may explain the poor animal performance usually observed during this portion of the grazing period. Gallavan et al. (1989) reported a strong positive linear relationship between DM concentration in wheat forage and DMI, but the DM content of the wheat forage used in their experiment was much lower than in the present experiment.

Supplementation strategies for cattle and sheep on wheat pastures usually are employed to compensate for a shortage of forage. Vogel et al. (1987) observed that steers increase the consumption of supplemental sorghum silage DM as the amount of wheat forage available for consumption decrease. They concluded that the steers preferred wheat forage to the supplemental silage, but would use the silage to fulfill daily DMI not met by the wheat forage. Lambs in the present experiment substituted wheat forage DM for supplemental DM on a one-to-one basis, which resulted in a relatively constant total DMI. In the present experiment, lambs tended to eat all of the corn provided while those offered hay consumed progressively smaller amounts. It is not clear if the preference for corn was due to physical form, taste or energy density. Hart et al. (1990) used a 72% concentrate supplement to compensate for increase stocking rate on spring wheat pastures. They concluded that lambs would consume the supplement to meet their nutrient needs not provided by the forage. If supplemental DM fed to ruminants grazing wheat forage is to be used efficiently, it should not compete with the forage for site of digestion and should provide nutrients which, if lacking, may limit animal performance (Vogel et al., 1989; McCann et al., 1991; Phillips et al., 1995a,b).

Compounding the problem of balancing DMI of supplements and forage is the change in forage nutrient composition during the grazing period. As cool season grasses mature, NDF and ADF concentrations increases, CP concentration decreases and DM digestibility decreases (Cherney and Marten, 1982a,b; McCann et al., 1991). Fall/winter wheat forage is immature and is predominately leaf material, but the proportion of stem in the forage mass increases rapidly with maturity (Phillips et al., 1995a). Nitrogen in wheat forage is very mobile, is transferred between shoots and roots and is constantly being recycled (Simmons, 1987). Therefore, it is not surprising to find a large portion of the total N in wheat forage in the soluble fraction. As wheat forage matures, total N concentration decreases and a smaller proportion of the total N is found in the soluble fraction (Gallavan et al., 1989; Phillips, 1986). It has been suggested that high concentrations of NPN and soluble N may have a detrimental affect on DMI (Gallavan et al., 1989). However, in our experiments a dramatic increase in soluble N and NPN concentrations were not observed. The presence of a high concentration of soluble N, and in particular NPN concentrations of more than 25% of the total N, has led some to theorize that low DMI or poor ADG during the first part of the wheat forage grazing season is due to adaptation to the NPN fraction of the forage (Phillips, 1986). Based on the present experiment, the period of time to achieve maximum DMI was less than the amount of time needed to adapt to NPN (Phillips, 1986).

Mader et al. (1983) observed similar ADG among steers grazing wheat pasture with and without ad libitum access to low-quality forages throughout the grazing period, but wheat forage availability was high and the DMI of low-quality forages was low. Vogel et al. (1987) used sorghum silage as a supplement to compensate for long-term deficiencies in available wheat forage. As stocking rate increased, intake of supplemental silage increased, but ADG was not affected. In other experiments where the supplement contained a low concentration of fiber and a high concentration of readily digestible carbohydrates, forage intake usually decreases as supplement intake increases (Chase and Hibberd, 1987; Phillips et al., 1995b). As a result, total digestible DM intake may not be increased because the increase in digestible DM provided by the supplement does not fully compensate for the depression in forage digestion.

Table 4. Body weight (BW), average daily gain (ADG) and supplemental dry matter intake (DMI) by feeder lambs grazing wheat pasture with and without supplementation (experiment 3).

Item	Treatments			
	WF[a]	CORN[b]	HAY[c]	SEM[d]
Number of lambs	66	62	69	–
Initial BW, kg	30.9[e]	27.7[f]	30.3[e]	0.6
Final BW, kg	45.8[e]	42.1[f]	43.4[e]	0.6
ADG, g	200[e]	193[f]	174[g]	3.0
Supplement DMI[h], g per day	0	196	246	22

[a] WF = wheat forage only.
[b] CORN = wheat forage plus corn.
[c] HAY = wheat forage plus hay.
[d] SEM = standard error of the mean.
[e,f,g] Means in the same row lacking a common superscript differ ($P < 0.05$).
[h] For the first 10 days.

Conclusions

In summary, voluntary intake of wheat forage during the first seven days of exposure to wheat forage is not limited by capacity. Under conditions where forage DM is very low, DMI capacity may be impacted by water content. In the present experiment, lambs need seven to 14 days to fully adapt to wheat forage and to achieve maximum forage intake. Lambs will substitute wheat forage for supplemental hay DM, but will not substitute supplemental wheat forage for corn DM. Daily consumption of supplements made primarily of forages would be self-limiting, whereas supplements composed of grain may need to be fed in limited quantities to reduce over-consumption. Feeding either hay or corn supplements during the first 10 days of the grazing period had a significant impact on overall ADG, but the magnitude of the decreases were small.

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Research Briefs

Acute Prenatal Androgen Treatment Increases Birth Weights and Growth Rates in Lambs

J.W. Gill
Univ. of Melbourne, Parkville, Victoria, Aust.

B.J. Hosking
Univ. of Melbourne, Parkville, Victoria, Aust.

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Males of most mammalian species, including sheep, are larger than females and their carcasses are leaner. The greater growth rate and leaner carcass composition exhibited by males, whether intact or castrated, is the result of testicular testosterone and its metabolites acting through sexual differentiation and activation of specific physiological processes. In sheep, most sexual differentiation occurs in utero during early fetal development. The study reported by Gill and Hosking is a continuation of work by Berger and co-workers at the University of Illinois and Klindt and co-workers at the U.S. Meat Animal Research Center. The objective of these studies has been to increase the concentrations of testosterone the fetal female lamb is exposed to during the period of sexual differentiation. Exposure of ewe fetuses to testosterone during the appropriate period can result in some development of male characteristics. The work from Illinois and MARC showed that postnatal growth rate and pattern of composition of ewe lambs had been masculinized or altered to be like that of males by administration of testosterone to the pregnant ewes for periods ranging from 3 to 10 weeks in length. However, growth of ewe lambs cannot be altered to be like that of rams because they lack testicles, and thus, testicular testosterone during the period of postnatal growth.

In one experiment, Gill and Hosking administered 200 mg of testosterone propionate to mature ewes as a single i.m. injection. In a second experiment, testosterone propionate was given at 30, 40, 50 or 60 days after synchronized mating. In these studies, testosterone propionate administration resulted in significantly increased birth weights of ewe lambs. The preweaning growth rates of the ewe lambs from testosterone propionate treated dams were increased 13% (33 grams per day). The greatest increases were seen in those born to dams treated at 60 days post-mating (22%, 61 grams per day) and the smallest increases in those born to dams treated at 40 days post-mating (7%, 17 grams per day). The authors report somewhat equivocal results to wool production during the preweaning period. The results certainly show that if there is an effect of testosterone propionate treatment on wool growth, it is negative (less wool produced).

These findings combined with those of others indicate that administration of testosterone as testosterone propionate or cypionate, during the 7th to 10th week post-mating is effective in enhancing growth rate of ewe lambs. This technology, prenatal androgen treatment, which was accomplished in this report through a single injection of 200 mg of testosterone propionate, has the potential of improving the efficiency of lamb production. Results from previous studies indicate these lambs may not be productively functional, thus this technology should be limited to terminal market lamb production. At the present, this treatment does not have regulatory approval for use in commercial lamb production.

–prepared by John Klindt

Breed Type and Sex Effects on Carcass Traits, Composition and Tenderness of Young Goats

D.D. Johnson
Univ. of Florida

C.H. McGowan
Florida A&M Univ.

G. Nurse

M.R. Anous
Ain Shams Univ., Cairo, Egypt

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Three genotypes of goats (Florida Native, Nubian × Florida Native, Spanish × Florida Native) and three sex groups (female, intact male, castrate) were used to study factors affecting carcass characteristics. Seventy-five head representing these sub-groups were slaughtered at six to eight months of age through the Meat Science Laboratory at the University of Florida. A number of live animal and carcass data were collected. One side of each carcass was dissected into bone and soft tissue. The latter was analyzed for fat and moisture percent. Leg steaks and loin chops collected from the other half of the carcass were subjected to Warner-Bratzler shear determinations. Nubian × Florida native crosses had significantly heavier live and carcass weight, but did not differ significantly in respect to dress-off items. Sex groups did differ in respect to dress-off items with males having a higher percent of head, feet, pelt, liver, heart and kidney than females, with castrates intermediate in respect to these measures. There was little difference between breed groups in respect to quality and yield indicators. The only significant difference being a lighter lean color score and a smaller ribeye area for the Spanish-Native crosses. In respect to the sex groups, the males had significantly less fat cover and kidney and pelvic fat. These results were as expected, but an unexpected finding was that males had less intense lean color. The male and castrates had significantly less fat and higher bone and lean than the females. They also tended to have higher shear force values. The overall conclusions were that breed type had minimal effect on carcass traits, but sex groups tended to have more substantial effects. Females had higher dressing percent, lower yields of dress-off items. Meat from female carcasses tended to be fatter and to be more tender.

– prepared by Maurice Shelton

Serological Diagnosis of Caprine Lentivirus Infection by Recombinant Immunoassays

J. Kwang
USDA-ARS, U.S. Meat Animal Research Center, Clay Center, NE

J. Keen
Univ. of Illinois, College of Vet. Med., Dept. of Vet. Pathobiology, Urbana, IL

R.C. Cutlip
USDA-ARS, National Animal Disease Center, Ames, IA

H.S. Kim
USDA-ARS, U.S. Meat Animal Research Center, Clay Center, NE

A. de la Concha-Bermejillo
Texas A&M Univ., Dept. of Pathobiology, Texas Ag. Exp. Sta., San Angelo, TX

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Lentiviruses cause chronic progressive disease in humans and domestic animals. Caprine arthritis encephalitis virus (CAEV) and visna-maedi are the prototypic lentiviruses of goats and sheep, respectively. North American isolates of ovine lentiviruses are usually referred to as ovine progressive pneumonia virus (OPPV). Infection with CAEV can result in chronic progressive arthritis, mastitis, encephalitis and lymphoid interstitial pneumonia. Because of their pathogenicity and persistent nature, lentiviruses are considered a threat to the livestock industry. For these reasons, the identification of lentivirus-infected animals is considered a critical issue. Serological tests, including the agar gel immunodiffusion (AGID) test and different ELISA formats, are the most commonly used methods for the diagnosis of lentivirus infections. Because of the immunological cross reactivity between CAEV and OPPV, serological tests that use whole OPPV or OPPV recombinant proteins may potentially be used for the identification of CAEV-infected animals.

In this paper, the sensitivity and specificity of two ELISA tests that use either a recombinant OPPV transmembrane protein (rTM-ELISA) or a recombinant p25 OPPV (rp25-ELISA) were compared to that of an AGID that uses the OPPV WLC-1 strain as antigen and to an ELISA that uses whole CAEV strain 63. The results of this experiment indicate that the rTM-ELISA test was more effective than the rp25-ELISA and the AGID test in identifying CAEV antibodies in the goat population. The sensitivity and specificity of rTM-ELISA and whole CAEV-ELISA were similar with an overall concordance of 87.5%. When the data for rTM- and rp25-ELISA were combined, the overall test agreement between rELISAs and whole CAEV-ELISA reached 89.3%. Although the effectiveness of OPPV recombinant protein-based ELISA tests can be used for the identification of CAEV-infected goats, the use of specific CAEV recombinant antigens for ELISA tests or CAEV strains for the AGID test may improve the sensitivity and specificity of both tests.

– compiled by A. de la Concha-Bermejillo

News and Notes

Sheep Check-Off

The producer referendum to decide if there will be a national sheep self-help program is now scheduled for late January or early February of 1996. Earlier this year, USDA announced that they anticipated the referendum would be held in October, but have since changed their plan. It is with the Beef and Pork referendums; the sheep vote will be conducted through the County Cooperative Extension Services offices. Be sure to read the various popular sheep publications or contact ASI for up-to-date information. Remember, all sheep owners are eligible to vote.

1996 Convention

The annual American Sheep Industry Convention will be held January 15 through 21, 1996, at the Hyatt Regency Hotel in Albuquerque, NM. For registration, schedule and hotel information, please contact ASI at (303) 771-3500.

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

In citing literature in the text, use both authors if there are only two. If there are more than two, use the first author and et al. Authors are asked to provide "interpretive summaries" for use by the sheep and goat industries in other media.

Proofing

Primary authors will receive galley proofs of articles. Corrected proofs should be returned by the deadline indicated. Failure to do so will result in delay of article publication.

Reprints

Fifty reprints of each article will be provided at no cost to the primary author. When galley proofs are sent, the author will be requested to complete a reprint order form requesting free and any additional reprints and provide the name of the institution, agency or individual responsible for the reprint charges.

Charge

The publication charge for the Sheep & Goat Research Journal is $60.00 per page and position announcements are $30.00 per quarter-page or less. Contributors will be billed following publication. All manuscripts and correspondence should be addressed to the Sheep & Goat Research Journal, 6911 South Yosemite Street, Englewood, CO 80112-1414, unless noted otherwise on materials received from the editorial staff.