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Contents:

Prediction of Cashmere Style Using Objective Fiber Measurements[1,2]

C.J. Lupton[3,4], F.A. Pfeiffer[3], and A.R. Dooling[5]

Summary

Multiple objective fleece and fiber measurements were made on 25 raw cashmere samples (5 of each style score [1-5] from cashmere goats) to establish mathematical relationships between the objectively determined characteristics and cashmere style score (CSS) subjectively assessed by an expert cashmere classer. Measurements included cashmere down yield (DY), average fiber diameter (AFD), guard hair and down staple lengths (GHSL and DSL), and average fiber curvature (AFC) of 2 mm snippets. The AFD and AFC were measured concurrently using an Optical Fibre Diameter Analyser. Cashmere style score was significantly correlated (in increasing order) with DSL, GHSL, AFD, and AFC. A second set of 25 raw cashmere samples was measured in the same manner and AFC was used to predict CSS. For actual versus predicted CSS, $r^2 = .63$ with a standard error of prediction (SEP) = 1 (cashmere style score units). Discriminant analysis confirmed that predicted CSS would invariably be within ± 1 unit of actual CSS.

Fiber curvature was shown to be the best single objectively measured trait for predicting cashmere style score. It should provide a useful, inexpensive, and potentially more accurate and consistent alternative for assessing this important trait.

Key words: cashmere, style, fiber curvature, objective fiber measurements.

Introduction

Cashmere style is an ill-defined but important characteristic of raw cashmere. Early attempts to define style invariably resulted in some objections from one segment of the industry or another. A definition of "good style" that has received some degree of acceptance in the U.S. is as follows: cashmere of good style has irregular crimp of relatively small magnitude and high frequency that does not lie in two dimensions but rather changes directions at irregular intervals along the length of individual fibers (Lupton, 1991). Straight fibers or those containing bold (mohair-like) or two-dimensional (like some fine wools) crimp are considered to have poor style. In an attempt to better describe the spectrum of cashmere styles currently being produced by goats in the U.S., a numerical scoring system was devised (by A.R. Dooling) that is being used in conjunction with subjective assessment.

Cashmere style is considered to be important by processors for several reasons: first, it distinguishes cashmere from other fine fibers; secondly, it affects the efficiency of the dehairing process and other mechanical processes up to spinning; and thirdly, it affects the hand (feel) of the finished fabric. Since cashmere goats were introduced into the U.S. in 1989, assessment of cashmere style has also been influenced (to varying degrees) by amount of luster in the down fibers, fleece color, down yield, average fiber diameter, and length of guard hair and down fibers. Intensive training is required for developing the ability to consistently and accurately assess style. Regular practice using fleeces of established style scores is necessary for the classer to retain the acquired skill. There has been a need to develop a method for objectively measuring cashmere style.

Recently, the manufacturer of the Optical Fibre Diameter Analyser (OFDA; Baxter et al., 1992) introduced a program for measuring snippet (a short fiber ~ 2mm in length) curvature (degrees/mm). This program has been used to measure curvature of wool snippets, a characteristic that has been shown to be highly correlated with fiber crimp and bulk (Edmunds and Sumner, 1996). The ob-

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jective of this study was to compare objectively measured fiber curvature and other fiber and fleece characteristics to subjectively assessed cashmere style.

Materials and Methods

A set of cashmere fleece samples (25) representing the broad spectrum of cashmere style scores (CSS; 1-5) was obtained from a U.S. cashmere buyer/manufacturer (Montana Knits, Inc., Dillon, MT). Cashmere style score was assessed for each sample by an expert cashmere classer. A score of 1 signified excellent style whereas a score of 5 meant poor style. Subsamples were removed from each raw cashmere sample and used to determine straightened down and guard hair staple lengths (DSL and GHSL, respectively) using a standard method of the American Society for Testing and Materials (ASTM, 1997). Subsequently, the remainder of each sample was dehaired using a Shirley Analyzer (International Wool Textile Organisation [IWTO], 1992) and the resulting separated down was quantified in terms of average fiber diameter (AFD; IWTO, 1995) and average fiber curvature (AFC; IWTO, 1997) using an OFDA. After separation, the guard hair and down portions from each sample were individually weighed, thus permitting calculation of cashmere down yield (DY). Stepwise multiple linear regression analysis was used to establish a linear relationship between dependant variable CSS and the objectively measured characteristics. In addition, correlation analysis was used to establish the linear relationships among all characteristics assessed, measured, and derived. A second set of 25 raw cashmere samples was then measured in the same manner as the first and AFC was used to predict CSS using the previously established regression equation. Next, simple linear regression analysis was used to examine the relationship between predicted and actual CSS. Finally, discriminant analysis was used to classify each sample of the second set in terms of CSS. All statistical analyses were conducted using the CORR, DISCRIM, MEANS, and REG procedures of SAS (SAS, 1996).

Results and Discussion

The simple statistics for variables estimated, measured, and derived from the two sets of raw cashmere samples are summarized in Tables 1 and 2. Mean values of each variable in the two sets were not different ($P > .05$) even though arithmetically, the first set of samples was slightly coarser (down AFD) and higher yielding than the second set. Stepwise multiple linear regression analysis of the first data set for dependant variable CSS resulted in only AFC and SD of AFC entering the model for $P < .1$ (producing an $r^2 = .64$. This occurred despite the significant correlations shown in Table 3 between CSS and down staple length, guard hair staple length, and down average fiber diameter, but not down yield). For this set of samples, CSS is obviously related to several other variables but most highly and significantly to average fiber curvature. The equation relating CSS, AFC, and SD of FC is:

$$CSS = 6.33 - .15 \times AFC + .10 \times SD\ of\ AFC.$$

After the second set of raw cashmere samples was objectively measured, the above equation was used to predict CSS. When predicted CSS were regressed against actual CSS values, an r^2 value = .63 was obtained with a SEP = 1 (CSS). Next, data generated using all 50 raw cashmere samples were analyzed by the stepwise multiple regression procedure for dependant variable CSS. This time GHSL entered the equation in step 2, in addition to AFC (step 1) and SD of AFC (step 3), to produce the following equation:

$$CSS = 6.90 - .26 \times GHSL - .12 \times AFC + .08 \times SD\ of\ AFC,\ \text{having an}\ r^2 = .70.$$

No other variables entered the equation below the $P < .3$ level. To further evaluate the accuracy of predicting classification variable CSS using objectively mea-

Table 1. Simple statistics for variables estimated, measured, and derived on the first set of raw cashmere samples.

Variable	Mean	SD	Minimum	Maximum
Cashmere style score, 1-5	3.0	1.4	1.0	5.0
Down staple length, in	2.9	.8	1.6	4.8
SD of down staple length, in	.4	.2	.1	.8
Guard hair staple length, in	3.1	1.3	1.7	5.9
SD of guard hair staple length, in	.6	.4	.2	1.8
Down average fiber diameter, mm	18.2	2.5	14.7	24.5
SD of down fiber diameter, mm	4.1	.8	2.9	6.5
Average fiber curvature, degrees/mm	59.4	11.3	35.6	80.2
SD of fiber curvature, degrees/mm	51.7	6.9	35.0	67.0
Down yield, %	54.5	18.5	18.8	91.5

sured data, the DISCRIM procedure of SAS was used to derive a linear discriminant function for CSS using the qualitative variables AFC, GHSL, and SDAFC of the first data set (the calibration data set). Subsequently, this discriminant function was used to classify each sample of the second set in terms of CSS. The results of this analysis are summarized in Tables 4 and 5. For the test data, only one predicted CSS value was more than one CSS unit greater than the actual value (a sample scored as a 5 was predicted to be at 3). All other predictions were within ± 1 CSS unit (as expected from the SEP calculated from the earlier regression analysis). The error rates (probabilities of misclassification) in the classification of future observations were .40 and .36 for the calibration and test data, respectively.

Correlation analyses for CSS versus all the other variables were conducted on the combined sets of 50 samples, and showed that CSS is significantly correlated with GHSL (r = -.48, P = .0004), AFD (r = .37, P = .008), SD of AFD (r = .48, P = .0004), AFC (r = -.77, P = .0001) and SD of AFC (r = -.51, P = .0002). In other words, better cashmere style scores (i.e., lower numbers) are associated with longer guard hair and finer, more uniform (in terms of AFD) down having higher fiber curvature values (i.e., more crimp). This conclusion would tend to confirm the "conventional wisdom" of most cashmere breeders. These data indicate that cashmere style is not associated with yield (P = .11).

Conclusions

This preliminary study indicates that average fiber curvature as measured by the

Table 2. Simple statistics for variables estimated, measured, and derived on the second set of raw cashmere samples.

Variable	Mean	SD	Minimum	Maximum
Cashmere style score, 1-5	3.1	1.4	1.0	5.0
Down staple length, in	3.1	.8	1.8	4.9
SD of down staple length, in	.3	.2	.1	1.2
Guard hair staple length, in	3.1	1.2	1.4	5.7
SD of guard hair staple length, in	.7	.5	.1	1.8
Down average fiber diameter, mm	17.0	1.7	14.7	20.6
SD of down fiber diameter, mm	3.7	.6	2.9	5.1
Average fiber curvature, degrees/mm	57.9	11.7	34.5	78.4
SD of fiber curvature, degrees/mm	52.6	6.7	39.0	68.0
Down yield, %	52.6	13.8	36.3	90.9

Table 3. Correlation coefficients and probability values for the linear relationships between cashmere style score (CSS) and the listed variables (first data set).

Variable	Correlation coefficient, r	Probability
Down staple length	.42	.04
SD of down staple length	-.04	.85
Guard hair staple length	-.42	.04
SD of guard hair staple length	-.03	.87
Down average fiber diameter	.53	.006
SD of down average fiber diameter	.60	.002
Average fiber curvature	-.74	.0001
SD of fiber curvature	-.42	.04
Down yield	.23	.27

Optical Fibre Diameter Analyser is significantly correlated with subjectively assessed cashmere style score. Further work is required to validate this conclusion for other cashmere classers and for a greater distribution of cashmere samples. The repeatability of individual subjective appraisers and variability among classers should also be established.

Implications

If the significant relationship between cashmere style score and fiber curvature holds true for other cashmere classers, then we will have discovered a simple, objective, potentially inexpensive, and likely a more consistent way to estimate cashmere style score. The AFC measurement should be inexpensive because it can be obtained concurrently with the down AFD measurement using the OFDA while incurring no extra cost. Such a measurement would be very useful to the many cashmere breeders who have not undergone the intensive training required to become a cashmere classer or who have undergone the training but failed to develop or maintain the necessary skill.

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Table 4. Classification summary for cashmere style score using the calibration data.

Actual	Total	Number of derived cashmere style scores				
classification	observations	1	2	3	4	5
1	5	4	0	1	0	0
2	5	1	3	0	1	0
3	5	0	1	1	3	0
4	5	0	1	2	2	0
5	5	0	0	0	0	5

Table 5. Classification summary for cashmere style score using the test data.

Actual	Total	Number of derived cashmere style scores				
classification	observations	1	2	3	4	5
1	4	4	0	0	0	0
2	5	3	2	0	0	0
3	5	0	0	3	2	0
4	7	0	0	1	3	3
5	4	0	0	1	0	3

Effects of Cyclic Feeding on Performance, Carcass Characteristics and Retail Value in Lambs[1,2]

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Summary

Thirty-seven Merino x Rambouillet lambs (body weight = 35.5 ± 3.8 kg; mean ± SD) were used to evaluate the effects of cyclic feeding on growth, average daily gain (ADG), carcass characteristics and composition, weight of retail cuts and retail value. Lambs were randomly allotted to one of three treatments and fed a pelleted diet for at least 56 days at 2 x net energy for maintenance (NE_m) requirements daily (control; five ewes and six wethers), 1.5 and 2.5 x NE_m cycled at 2-day intervals (2D; seven ewes and six wethers) or 1.5 and 2.5 x NE_m cycled at 4-day intervals (4D; seven ewes and six wethers). Thereafter, animals were fed until they reached a live weight of 46.0 ± 0.6 kg (slaughter weight). Lambs were weighed every 8 days. Hot carcass weights were obtained and carcass characteristics were determined 24 hours postmortem. The 10th through the 12th rib section of the right side was removed, dissected into lean, fat, bone and tendon and chemical composition of soft tissue was determined. Carcasses were fabricated into primal/subprimal retail cuts, weighed, and priced for retail sale. Days on feed and ADG were not influenced ($P > 0.11$) by cyclic feeding. Hot and chilled carcass weights, dressing percentage, flank streaking, leg conformation, and rib-eye area were not affected ($P > 0.16$) by cyclic feeding. Controls had more ($P < 0.03$) backfat and body wall fat than 2D and 4D lambs. Fat content was greater ($P = 0.04$) in rib sections of control lambs. Cyclic feeding did not influence ($P > 0.85$) either weight or value of retail cuts or total carcass retail value. Alternating feed DMI does not influence rate of gain or days on feed; however, cyclic feeding does reduce backfat thickness without negatively affecting carcass lean content or retail value.

Key words: lamb, growth, carcass composition, retail cuts

Introduction

Feeding lambs for lower rates of gains, either by restricting feed intake or reducing the energy density of the diet has been shown to decrease carcass fat content (Burton et al., 1974; Drew and Reid, 1975;Murphy et al., 1994). Nonetheless, feeding for lower gains increases days on feed and increases overhead costs to the producer. Management systems that can reduce fat deposition without increasing days on feed would be of benefit.

In this regard, Estell et al. (1993) conducted a study with a feeding program that involved alternating energy intake levels every 4 days. Animals were fed in a cyclical pattern 1 x NE_m for 4 days, followed by 2 x NE_m for 4 days for a 64 day period. Following the cyclic feeding period, lambs received an above maintenance diet for 2 months. During the cyclic feeding period, lambs receiving alternating energy intake tended to have higher ADG, gain/feed ratio than control lambs, but carcass characteristics measurements obtained 2 months later, did not differ between treatments. These results suggest possible benefits of cyclic feeding. In addition, feeding above maintenance for 2 months after cyclic feeding may have overridden any affect cyclic feeding had on carcass traits. Further

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evaluation of cyclic feeding is warranted based on their limited results. Therefore, the objective of this study was to determine if alternating dietary dry matter intake levels affected ADG, feed efficiency, carcass characteristics and composition, and weight and value of retail cuts in lambs

Materials and Methods

Animal Management

Forty-two Rambouillet x Merino lambs (21 wether and 21 ewe lambs;approximately 5 months of age; average initial body weight = 35.5 ± 3.8 kg; mean ± SD) were dewormed (Panacure, Hoechst-Roussel Agri-Vet Co., Somerville, NJ) and vaccinated against enterotoxemia C/D (Colorado Serum Co., Denver, CO) 40 days before study initiation. Lambs were sheared 1 month before the study began. Thirty-four days before study initiation, lambs were placed in individual pens (1.22 x 2.44 m), and fed a 50:50 ratio of alfalfa pellet:concentrate pellet to meet 2 x NE_m requirements for each lamb on a body weight basis (Table 1). Animals were gradually adapted to the concentrate pellet for 22 days, then fed only the concentrate pellet for 5 days. Several lambs refused to eat the concentrated pellet so all lambs were readapted to a 25:75 ratio of alfalfa pellet:concentrate pellet for 7 days. Lambs received the 25:75 ratio combination diet throughout the study.

Lambs were randomly allotted with respect to body weight to one of three treatments (seven ewe and seven wether lambs/treatment) immediately following the 7 day adaptation period to the 25:75 alfalfa pellet:concentrate pellet diet. Average body weights at the start of study were similar across treatments. Control animals were fed 2 x NE_m (NE_m requirement = 56 kcal/$BW^{0.75}$; NRC, 1985) daily. The cyclic feeding treatments involved alternating energy intake at 1.5 x NE_m and 2.5 x NE_m at 2-day intervals (2D) or at 4-day intervals (4D). These treatments average two times maintenance over a 4-day (2D) or 8-day (4D) period.

A composite feed sample for both pelleted feeds were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL, Goering and Van Soest, 1970). Ash, dry matter (DM), Kjeldahl N, and crude fat percentages were determined as outlined by AOAC (1990) except a 1:1 ratio of chloroform:methanol was used for the crude fat procedure.

All lambs were fed their designated treatment at 0700 hours and allowed free access to water and trace mineral salt (Champions Choice trace mineralized salt; Akzo Salt, Inc., Clarks Summit, PA; guaranteed analysis [percentage of dry matter]: NaCl, 95 to 99; Zn, 0.35; Fe, 0.34; Mn, 0.20; Cu, 0.033; I, 0.007; and Co, 0.005). Lambs were weighed before the morning feeding on day 1 of the study and every 8 days thereafter. Individual animal feed intake was adjusted based on the most recent body weight. Feed refusals were weighed if necessary. All animal care followed procedures outlined previously (Consortium, 1988).

Carcass Characteristics

All lambs were fed for at least a 56-days

Table 1. Ingredients and chemical composition of the two pelleted feeds fed to lambs.

Item	Pelleted Grain	Pelleted Alfalfa
Corn grain, %	1.0	0.0
Oat grain, %	21.0	0.0
Barley grain, %	21.0	0.0
Alfalfa hay, %	11.5	80.0
Soybean meal, %	8.0	0.0
Molasses, %	5.0	0.0
Dicalcium phosphate, %	1.0	0.0
Salt, %	1.0	0.0
Ammonium sulfate, %	0.5	0.0
Grain, %	0.0	20.0
DM, %	92.5	90.9
	% of DM	
NDF	29.2	31.7
ADF	11.3	27.2
ADL	2.4	5.2
Crude protein	12.3	12.0
Ash	5.8	8.3
Crude fat	14.5	15.7

period. Feeding continued until lambs reached approximately 46.0 kg at which time lambs were slaughter at the University of Nevada Meats Laboratory. Lambs were weighed the morning of slaughter after a 24-hour shrink. Hot carcass weight was determined after dressing and before placing in cooler (approximately 30 minutes after slaughter). Following a 24-hour chill (2°C), cold carcass weight and factors used to determine USDA quality grade were obtained and loin eye area traced. Loin eye area was determined using a compensating polar planimeter. Backfat depth was measured over the center of the longissimus muscle between the 12th and 13th ribs, and total body wall thickness was measured between the 12th and 13th ribs at 15 cm lateral to the midline. Quality grade was based on maturity, conformation, and flank streaking. Yield grades were calculated using chilled carcass measurements of backfat thickness (USDA, 1992). Following a 48-hour chill, kidney and pelvic fat and kidney weights were obtained.

Retail Cuts

At the University Meats Laboratory, following the 48-hour chill, each carcass was weighed and fabricated into the following primal/subprimal cuts: a) single legs, (U.P.C. item No. 2964) with the hindshank removed; b) sirloin chops (U.P.C. item No. 2984); c) loin chops (U.P.C. item No. 2955); d) rib chops (U.P.C. item No. 2948); e) shoulder (blade) chops (U.P.C. item No. 2922); f) arm (shoulder) chops (U.P.C. item No. 2919); g) breast (U.P.C. item No. 3003); h) foreshank (U.P.C. item No. 3010); i) hindshank (U.P.C. item No. 2978); j) neck stew meat; k) flank and; l) outside skirt (NLSMB, 1995). All cuts were trimmed to contain a maximum external fat thickness of .31 cm. The neck and the small adjoining shoulder section was cut into bite size pieces and packaged for crockpot meals. Another retail cut was fabricated using the breast and boneless trim from the flank and outside skirt. A specialty retail cut (Wolfpack Chop) was produced by trimming the breast so that it contained a maximum of .31 cm of external fat, with the ribs cut from the costal cartilage. A pocket was made between the lean and the rib bones. The flank, outside skirt and other lean trim from the carcass was ground and stuffed into the pocket, after which a transverse cut was made between the ribs producing an approximately 2.54 cm thick Wolfpack Chop. Two chops were sold per package. Each package of trimmed retail lamb cuts was weighed immediately after fabrication, wrapped, labeled and priced for retail sale, creating a case ready product. The retail grocery company, Scolaris Food and Drug Company, Sparks, NV established retail cut prices. Retail cuts from the right and left side were boxed and distributed to 10 retail stores within the grocery chain.

Weights were recorded for fat trim and bone removed from carcasses during retail processing. An aggregate weight (the sum of the individual weights of all fabricated carcass components) was determined and used as a carcass weight to calculate the percentage of each carcass component. The weight of major lamb cuts was determined using the sum of the

Table 2. Average daily gain (ADG), days on feed, and gain/feed ratio (G/F) of lambs as influenced by pattern of dry matter intake and sex of lamb.

	Treatment[a]				Sex		
	Control	2D	4D	SE	Ewe	Wether	SE
n = 11	n = 13	n = 13	n = 19			n = 18	
Initial wt, kg[b]	35.2	34.7	36.3	1.2	33.5	37.3	0.9
Weight at 56 days, kg[b]	43.1	42.9	44.5	1.2	41.7	45.2	0.9
Final weight, kg[b]	46.4	46.0	45.4	0.6	44.9	47.0	0.5
Total gain, kg[c]	11.2	11.3	9.1	0.7	11.4	9.7	0.5
ADG (g/d)							
Day 1-56	141	146	146	9.2	146	141	7.2
Entire feeding period[b]	122	119	100	5.0	106	116	4.2
Days on feed[d]	92.4	98.1	96.6	7.4	107.5	83.6	5.7
G/F (g/kg)							
Day 1-56[c]	155	151	128	8.2	151	138	6.9
Entire feeding period	120	112	101	6.4	108	114	5.0

[a] Control = 2 x NE_m daily, 2D = 1.5 x NE_m and 2.5 x NE_m alternated at 2-day intervals, and 4D = 1.5 x NE_m and 2.5 x NE_m alternated at 4-day intervals.
[b] Ewe vs wether ($P < 0.08$).
[c] 2D vs 4D ($P < 0.05$).
[d] Ewe vs wether ($P = 0.02$).

weights for the shoulder blade, arm, rib, sirloin and loin chops, and legs. Total trimmed lamb cuts included major cuts plus neck stew meat and shanks. The percentage yields of trimmed cuts were obtained from the cold carcass weight with kidneys plus kidney and pelvic fat removed.

Laboratory Analyses

Rib Sections. Following the 48-hour chill, the 10th through 12th rib section of the right side was removed from a short-cut (5 cm) IMPS 204 rack, vacuum packaged and frozen at approximately -20°C. After termination of the study, all ribs were thawed, weighed, dissected into muscle, fat, and bone and tendon. Individual tissues were weighed as soon as dissection was completed to minimize weight loss. Fat and muscle were then vacuum packed and refrozen. Soft tissue was thawed, lyophilized using a Virtis freeze dryer (Gardner, NY), and ground with dry ice in a blender until completely mixed for use in chemical composition analysis. Subsamples were taken of the ground material, weighed, and analyzed for DM, crude protein (CP) and ash (AOAC, 1990). Lipids were extracted using the crude fat procedure outlined by AOAC (1990), except a 1:1 ratio of chloroform:methanol was used.

Statistical Analysis. Two control ewes, and one control, 2D, and 4D wether were excluded from analysis due to either physical abnormalities or health problems. Only one lamb (4D treatment) was removed just prior to reaching slaughter weight because it developed laminitis, which may have been associated with cyclic feeding. Animal weights, ADG, carcass characteristics and retail data were evaluated by analysis of variance for a completely randomized design (CRD) in a 3 x 2 (treatment x sex) factorial arrangement using GLM procedure of SAS (1988). Nonparametric carcass data were analyzed using CATMOD procedures of SAS (1988). Following a significant F test ($P < 0.10$) treatment effects were analyzed using contrasts (Steel and Torrie, 1980); control vs 2D, and 4D treatments and 2D vs 4D treatments. No treatment by sex interactions were detected ($P > 0.10$) for any of variables measured so only treatment and gender effect variables are reported.

Results and Discussion

Feed Intake and Growth Performance

Average daily gain and days on feed were not affected ($P = 0.63$, $P = 0.15$, respectively) by cyclic feeding for the first 56

Table 3. Carcass characteristics of lambs as influenced by pattern of dry matter intake and sex of lamb.

	Treatment[a]				Sex		
Item	Control n=11	2D n=13	4D n=13	SE	Ewe n=19	Wether n=18	SE
Slaughter wt, kg[e]	46.3	45.9	45.7	0.6	45.0	47.0	0.5
Hot carcass wt, kg	23.4	23.1	23.0	0.3	23.0	23.4	0.2
Chilled carcass wt, kg	22.7	22.5	22.3	0.3	22.3	22.7	0.2
Kidney and pelvic fat, g[e]	860.4	885.2	860.2	82.2	960.4	776.8	64.0
Backfat, cm[bef]	.37	.30	.28	0.03	.35	.28	0.02
Body wall fat at 15 cm[bef]	1.52	1.33	1.27	0.07	1.42	1.33	0.06
Dressing %[e]	50.5	50.4	50.3	0.8	51.1	49.7	0.6
Leg conformation[ce]	10.5	9.9	9.5	0.3	10.3	9.6	0.3
Flank streaking[d]	521.2	516.4	494.2	10.9	517.9	503.3	8.5
Conformation[ce]	10.7	10.3	9.9	0.3	10.6	10.0	0.2
Quality grade [ceg]	10.8	10.3	10.0	0.3	10.7	10.1	0.2
Loin eye area, cm²	10.3	10.5	9.6	0.3	10.1	10.2	0.3

[a] Control = 2 x NE_m daily, 2D = 1.5 x NE_m and 2.5 x NE_m alternated at 2-day intervals, and 4D = 1.5 x NE_m and 2.5 x NE_m alternated at 4-day intervals.
[b] Measured between 12th and 13th ribs.
[c] Choice$^+$ = 12, choice = 11, choice$^-$ = 10, good$^+$ = 9.
[d] Small$^+$ = 566, small = 533, small$^-$ = 500, slight$^+$ = 466.
[e] Ewe vs wether ($P < 0.09$).
[f] Control vs 2D and 4D ($P < 0.05$).
[g] Control vs 2D and 4D ($P = 0.06$).

days or throughout the study (Table 2). However, total gain and gain to feed (G/F) ratio were greater ($P < 0.05$) in 2D lambs compare to 4D lambs. In contrast, Estell et al. (1993) reported lambs fed 1 and 2 x NE_m in 4-day intervals tended ($P = 0.15$) to have higher ADG than control lambs when cyclic fed over a 64-day period. Additionally, Estell et al. (1993) reported that gain to feed ratios tended ($P = 0.12$) to be lower in cyclic-fed lambs than control lambs. Differences in results between Estell et al. (1993) and the present study may reflect differences in the plane of nutrition and (or) composition of diet; Estell et al. (1993) fed a 40% concentrate diet while in the present study a higher percentage of concentrate was fed.

As expected, wether lambs had greater ($P = 0.04$) ADG than ewe lambs for the entire trial (Table 2) and wether lambs had fewer ($P = 0.02$) days on feed, probably because their initial starting weights were heavier and ADG greater ($P < 0.08$) than ewe lambs. No differences were observed ($P = 0.18$) between ewe and wether lambs for G/F ratio for either the first 56 days of the trial or for the complete study. Conversely, Ferrell et al. (1979) reported wether lambs gained more rapidly and required less feed per kg of gain than ewe lambs. In the present study, feed efficiency of ewes was similar to wethers and may have resulted from the greater initial weights of the wethers. As body weight increases, the composition of gain becomes more energy dense requiring a greater caloric density of the diet for each incremental increase in gain or maintenance of gain.

Gains for all groups were below maximal production level associated with growing lambs. Nutrient intake levels were below those typically offered in practice but allowed for several cycles of intake fluctuations. Predicated gains of 200 g/day were greater than actual gains. Estell et al. (1993) also reported similar findings and suggested this difference between predicted and obtained gains may be because the diet was pelleted and resulted in greater rate of passage through the gastrointestinal tract, hence causing reduced digestibility without allowing for the nominal increase in intake. Refusals rarely occurred, and usually occurred on the last day of high levels of feeding in the 4D treatment rather than due to digestive disturbances. It is possible that more problems may have occurred if the shifts in nutrient levels had been greater than 1.5 and 2.5 x NE_m.

Carcass Data

Cyclic feeding had no affect ($P > 0.49$) on live slaughter, hot or chilled carcass weights (Table 3) and are similar to weights for cyclic-fed wethers reported by Estell et al. (1993). Likewise, kidney and pelvic fat weight, dressing percentage, leg conformation, flank streaking, and loin eye area were not influenced ($P > 0.16$) by cyclic feeding. Control lambs had higher ($P = 0.06$) quality grades than cyclic-fed lambs, which likely reflects the increased fat cover in control lambs. All lambs had a yield grade of either 1 or 2 with 54.5% of the control lambs (6/11 lambs), and 92.3% of the 2D and 4D lambs

Table 4. Physical and chemical composition of the 10th and 12th right rib section as influenced by pattern of dry matter intake and sex of lamb.

	Treatment[a]				Sex		
Item	Control n = 11	2D n = 13	4D n = 13	SE	Ewe n = 19	Wether n = 18	SE
Rib section							
Total weight, g[b]	320.97	301.79	290.04	10.22	299.70	308.83	7.96
Total weight, g[c]	319.46	300.41	288.53	10.23	298.11	307.48	7.96
Fat, g[d]	111.08	95.75	89.88	5.9	100.18	97.63	4.6
Bone, g[e]	71.83	71.45	70.02	3.3	66.81	75.39	2.6
Lean, g	137.46	133.20	128.58	5.6	131.15	135.01	4.4
Chemical composition	% (DM basis)						
Rib ash	1.91	1.78	1.84	0.13	1.82	1.87	0.11
Rib fat	29.70	31.58	31.68	2.71	30.88	31.09	2.19
Rib protein	68.39	66.63	66.47	2.88	67.30	67.04	2.24

[a] Control = 2 x NE_m daily, 2D = 1.5 x NE_m and 2.5 x NE_m alternated at 2-day intervals, and 4D = 1.5 x NE_m and 2.5 x NE_m alternated at 4-day intervals.
[b] Total weight of right rib section before physical separation.
[c] Total weight of right rib section after physical separation.
[d] Control vs 2D and 4D ($P = 0.02$).
[e] Ewe vs wether ($P = 0.02$).

Table 5. Weight of individual retail cuts and weight and percentages of trimmed retail cuts of lambs as influenced by pattern of dry matter intake and sex of lamb.

	Treatment[a]				Sex		
Item	Control n = 11	2D n = 13	4D n = 13	SE	Ewe n = 19	Wether n = 18	SE
Carcass characteristics							
Cold carcass, kg	21.09	20.97	20.94	0.27	20.79	21.18	0.21
Bone, kg[d]	1.89	1.92	1.97	0.03	1.88	1.96	0.03
Fat, kg[d]	2.32	2.24	2.07	0.12	2.37	2.07	0.09
Total retail cuts, kg[e]	16.88	16.81	16.90	0.29	16.54	17.15	0.24
Retail cuts, kg							
Neck stew meat[d]	0.86	0.88	0.89	0.02	0.84	0.91	0.02
Blade chops[d]	2.39	2.45	2.38	0.04	2.34	2.47	0.04
Arm chops[d]	1.05	1.04	1.03	0.05	1.01	1.07	0.02
Shanks[d]	1.74	1.74	1.75	0.04	1.70	1.77	0.03
Rib chops[f]	1.27	1.21	1.21	0.04	1.20	1.26	0.04
Loin chops[e]	1.44	1.43	1.43	0.04	1.39	1.47	0.03
Sirloin chops	0.92	0.90	0.93	0.05	0.90	0.93	0.04
Legs	4.04	3.97	4.02	0.11	4.00	4.02	0.08
Wolfpack chops	3.17	3.19	3.26	0.08	3.16	3.25	0.14
Major trimmed retail cuts[b]							
Weight, kg[f]	11.1	11.0	11.0	0.22	10.8	11.2	0.17
% of cold carcass weight[e]	52.6	52.5	52.5	0.70	51.9	52.8	0.53
Total trimmed retail cuts[c]							
Weight, kg[ef]	13.7	13.6	13.6	0.26	13.4	13.9	0.20
% of cold carcass weight[d]	64.7	64.9	65.0	0.79	64.3	65.6	0.61

[a] Control = 2 x NE_m daily, 2D = 1.5 x NE_m and 2.5 x NE_m alternated at 2-day intervals, and 4D = 1.5 x NE_m and 2.5 x NE_m alternated at 4-day intervals.
[b] Sum of the weights for the shoulder, arm, rib, sirloin and loin chops, and legs.
[c] Total trimmed lamb cuts included major cuts plus neck stew meat and shanks.
[d] Ewe vs wether ($P < 0.04$).
[e] Ewe vs wether ($P < 0.09$).
[f] Includes the 10[th] through the 12[th] rib section of the right side.

(12/13 lambs) yield grading 1 (control vs 2D and 4D; P = 0.11). Field et al. (1990) reported that lambs fed either a high or low plane of nutrition, and slaughtered at similar weights had comparable cold carcass weights, however, lambs receiving the high plane of nutrition had higher quality and yield grades. These authors also showed that lambs receiving a high plane of nutrition had higher leg conformation, flank streaking, kidney and pelvic fat weight and loin eye area than those receiving a low plane of nutrition. Differences between studies may be a reflection of actual slaughter weights. In our study, lambs were slaughtered at lighter weights, and may not have reached similar carcass maturity to reflect changes in carcass characteristics. Backfat and body wall fat at 15 cm were greater ($P < 0.03$) in control lambs than 2D and 4D lambs.

Plane of nutrition has been shown to affect fat deposition. Murphy et al. (1994) fed lambs a concentrate diet consisting of 70, 85 or 100 % ad libitum intake. Lambs that were restricted-fed had lower backfat thickness than lambs fed ad libitum. Restricting nutrient intake has usually resulted in greater days on feed. In the present study, no difference in days on feed was noted between cyclic-fed lambs and control lambs, but backfat thickness and body wall thickness was reduced by cyclical feeding. This change would suggest cyclical feeding resulted in leaner gain without increasing days on feed. In this regard, Glimp and Snowder (1989) stated that with diets that do not support rapid growth, protein gain remains relatively constant per unit of weight change, whereas fat gain or loss will vary depending on rate of gain.

Ewe lambs weighed less (P = 0.08) than wether lambs at slaughter (Table 3). Yield grade was not affected (P = 0.12) by sex of lamb; 73.7% of the ewe lambs (14/19 lambs) and 77.8% of the wether lambs (14/18 lambs) had a yield grade 1. Similarly, Everitt and Jury (1966) slaughtered wether lambs at heavier weights than ewe lambs, and found no differences in yield grades between sexes. Ewe lambs had (P < 0.09) more kidney and pelvic fat, backfat, and flank streaking, and higher (P < 0.09) dressing percentage, leg and overall conformation scores, and quality grade than wether lambs (Table 3). Everitt and Jury (1966) showed that fat depth did not differ between ewe and wether lambs, but they slaughtered lambs at a younger age and at lighter weights, perhaps before differences in carcass composition could be detected.

Rib Section Analysis

Rib section (bone, cartilage, muscle and fat) analysis obtained from the 10th to 12th rib of the right side showed fat content was greater (P = 0.02) in control lambs than in cyclic-fed lambs and supports the results observe for backfat. Bone and lean tissue, however, did not differ (P > 0.33) among treatments (Table 4). Chemical composition of the intercostal muscle and associated fat was not affected (P > 0.33) by treatment; no differences were observed in percentage of ash, fat, or protein content and are comparable to values reported by Estell et al. (1993).

Analysis of the three rib section showed no difference (P > 0.53) for fat or lean between wether and ewe lambs, but wethers did have more bone (P = 0.02) than ewes (Table 4) which may be due to splitting error. However, Palsson and Verges (1952) showed wether lambs had more bone compared to ewe lambs but reported no difference in lean tissue. No differences (P > 0.53) were observed in ash, crude fat, or protein chemical content between wether and ewe lambs which agree with the findings of Bass et al. (1989).

Carcass Retail Cuts

Cyclic feeding did not affect (P> 0.90) 48-h chilled carcass weight or total kg of retail cuts (Table 5). Likewise, neither bone nor fat removed from the carcass during retail fabrication was affected by cyclic feeding. However, percentage of bone was greater (P = 0.07) in cyclic-fed lambs than in control lambs (Table 6), however, these differences were small and would seem to be of little biological significance. Interestingly, although cyclic feeding increased measures of estimating external fat, no difference (P = 0.35) in fat trim was observed. Dietary treatment

Table 6. Retail cuts as a percentage of cold carcass weight of lambs fed different patterns of dry matter and by sex of lamb.

	Treatment[a]				Sex		
	Control	2D	4D	SE	Ewe	Wether	SE
Item	n = 11	n = 13	n = 13		n = 19	n = 18	
Bone, %[b]	9.0	9.1	9.4	0.1	9.0	9.2	0.1
Fat, %[d]	11.0	10.8	9.9	0.6	11.4	9.8	0.5
Neck stew meat, %[c]	4.1	4.2	4.2	0.1	4.0	4.3	0.1
Blade chops, % [c]	11.4	11.7	11.4	0.1	11.3	11.7	0.08
Arm chops, %[d]	5.0	4.9	4.9	0.1	4.9	5.0	0.05
Shanks, %[d]	8.2	8.3	8.4	0.2	8.2	8.4	0.1
Rib chops, % [e]	6.1	5.8	5.8	0.2	5.8	5.9	0.1
Loin chops, %	6.8	6.8	6.8	0.2	6.7	6.9	0.1
Sirloin chops, %	4.3	4.3	4.4	0.2	4.3	4.4	0.2
Legs, %	19.1	18.9	19.2	0.4	19.2	19.0	0.3
Wolfpack chops, %	15.0	15.2	15.6	0.3	15.2	15.4	0.2

[a] Control = 2 x NE_m daily, 2D = 1.5 x NE_m and 2.5 x NE_m alternated at 2-day intervals, and 4D = 1.5 x NE_m and 2.5 x NE_m alternated at 4-day intervals.
[b]Control vs 2D and 4D (P < 0.07).
[c]Ewe vs wether (P < 0.10).
[d]Ewe vs wether (P < 0.05).
[e]Includes the 10th through the 12th rib section of the right side.

did not influence (P > 0.20) any retail cuts examined and is in agreement with the rib data. Weight of major trimmed retail cuts and major trimmed retail cuts as a percentage of chilled carcass did not differ (P > 0.45) among treatments and are similar to those reported by Snowder et al. (1994). Furthermore, weight of total trimmed retail cuts and total trimmed retail cuts as a percentage of cold carcass weight were not affected (P > 0.15) by cyclic feeding (Table 7). These results suggest cyclic feeding has little influence on the amount of lean produced by lambs slaughtered at approximately 46 kg of live weight.

Sex of lamb had no affect (P = 0.50) on chilled 48-h carcass weight; however, ewe carcasses had more (P = 0.04) fat and less (P = 0.04) bone removed than wether carcasses (Table 5). These findings are not surprising because the proportion of bone in the carcass is usually inversely related to the fat content in sheep of similar breeding, age and weight (Jeremiah et al., 1997a). As a percentage of chilled carcass weight, fat trim was greater (P = 0.30) in ewe lambs compared to wether lambs; however, no difference (P = 0.19) was noted for carcass bone removal (Table 6). Wether carcasses produced more (P = 0.08) total kilograms of retail cuts than ewe carcasses (Table 5). This difference likely reflects, at least in part, the greater quantity of trimmed fat from ewe carcasses. Retail cuts were affected by the sex of lamb. Wether carcasses had more (P < 0.09) blade, arm, and loin chops, neck stew meat, and shanks than ewe carcasses (Table 5). These retail cuts as a percentage of cold carcass weight

Table 7. Dollar value of retail cuts in lambs as influenced by different patterns of dry matter intake and sex of lamb.

Item, $ value	Treatment[a] Control n = 11	2D n = 13	4D n = 13	SE	Sex Ewe n = 19	Wether n = 18	SE
Retail cut value							
Neck stew meat, ($ 1.69/.454 kg)[c]	3.20	3.27	3.31	0.10	3.12	3.38	0.07
Blade chops, ($ 3.99/.454 kg)[c]	21.00	21.53	20.92	0.41	20.56	21.70	0.31
Arm chops, ($ 4.29/.454 kg)[d]	9.92	9.92	9.73	0.20	9.54	10.11	0.16
Shanks, ($ 2.69/.454 kg)[d]	10.30	10.30	10.36	0.22	10.07	10.48	0.17
Rib chops, ($ 8.99/.454kg)[b]	25.15	23.96	23.96	0.98	23.76	24.95	0.76
Loin chops, ($ 8.79/.454 kg)[c]	27.88	27.69	27.69	0.73	26.91	28.46	0.60
Sirloin chops, ($ 7.99/.454 kg)	16.19	15.84	16.38	0.90	15.83	16.38	0.70
Legs, ($ 3.59/.454 kg)	31.95	31.39	31.79	0.89	31.63	31.79	0.70
Wolfpack chops, ($ 2.99/.454 kg)	20.88	21.00	21.47	0.55	20.81	21.40	0.42
Total value/carcass							
Wholesale value/ carcass, ($ 3.19/.454 kg)[d]	118.60	118.11	118.74	2.16	116.21	120.50	1.68
Retail value/ carcass[c]	166.47	164.90	165.61	3.12	162.23	168.65	2.41
Gross margin[c]	47.87	46.79	46.87	1.07	46.02	48.15	0.83

[a] Control = 2 x NE_m daily, 2D = 1.5 x NE_m and 2.5 x NE_m alternated at 2-day intervals, and 4D = 1.5 x NE_m and 2.5 x NE_m alternated at 4-day intervals.
[b]Represents the rib minus the 10th through the 12th rib section of the right side.
[c]Ewe vs wether (P < 0.10).
[d]Ewe vs wether (P < 0.05

differed ($P < 0.10$) between wether and ewe lambs (Table 6). No differences ($P > 0.45$) were observed for rib and sirloin chops, legs and Wolfpack chops between wether and ewe carcasses (Table 5). Likewise, these retail cuts as a percentage of chilled carcass weight were not affected ($P > 0.50$) by sex of lamb (Table 6). Jeremiah et al. (1997b) reported similar results for retail cuts, except the proportion of loin did not differ between wethers and ewes. Major trimmed retail cuts (shoulder, arm, rib, sirloin and loin chops and legs, kg) tended to differ ($P = 0.12$) between ewe and wether carcasses. Wether carcasses yielded more ($P = 0.09$) major trimmed retail cuts as a percentage of carcass weight (Table 5). Likewise, total trimmed retail cuts (included major cuts plus neck stew meat and shanks, kg) and trimmed retail cuts as a percentage of chilled carcass weight were greater ($P < 0.09$) in wethers than ewes.

Cyclic feeding did not influence ($P > 0.85$) retail cuts or wholesale carcass value (Table 7). Likewise, neither total carcass retail value nor gross margin were affected ($P > 0.90$) by cyclic feeding with all treatments returning an approximately $ 165.00 per carcass and a gross margin of approximately $ 47.00 per carcass. Although lambs in the control group had more external fat than cyclic-fed lambs, the increase was not reflected by an increase in fat trim or a decrease in retail value.

Value of retail cuts were affected ($P < 0.10$) by sex of lamb (Table 7). For wether lambs, neck stew meat, blade and arms chops, shanks and loin chops were worth more ($P < 0.10$) than ewe lambs, reflecting the increase in retail weight of wether carcasses. Sex of lamb did not affect ($P > 0.40$) the value of the rib chops, Wolfpack chops or legs. Total wholesale and retail carcass values were worth more ($P < 0.10$) for wethers than ewes. These results are in agreement with Oliver et al. (1967) who reported wether lambs produced a significantly larger percent of total consumer retail cnts and retail value per unit of carcass weight than ewe lambs. Wether lambs were worth $ 4.29 more per wholesale carcass and an additional $ 2.13 per carcass to the retailer because of the reduced trim loss and increase in sellable retail cuts. Wether lambs with similar carcass weights as ewe lambs produce more retail cnts, thereby, increasing both wholesale and retail value.

Implications

Cyclic feeding reduces external fat with no negative effects on retail cuts in ewe and wether lambs, thereby, producing a more desirable product for the consumer. Additionally, lambs fed alternating energy levels at 2-day intervals had similar days on feed and G/F ratio as control lambs with no observed health problems, suggesting possible benefits of feeding in 2-day cycles as compared to 4-day cycles. Therefore, further research to evaluate the effects of number and length of individual cycles, possible levels of intake and energy shifts which might improve lamb production without incurring problems associated with digestive disorders is warranted.

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Effects of Immunoglobulin Treatment and Genetic Type on Survival and Preweaning Growth Performance of Lambs[1]

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Summary

A cooperative project involving a total of 842 lambs, located at university sheep research units in Iowa, Kansas, and Kentucky, was conducted to study effects of immunoglobulin treatment, genetic type, and type of rearing on lamb survival and preweaning growth performance. Every other single lamb and one of every pair of twin lambs born at each of the three sites in the fall of 1994 was treated within 10 h of birth via subcutaneous injection with 10 cc of a commercial immunoglobulin serum. The serum contained antibodies from five organisms commonly associated with diarrhea and respiratory problems in newborn lambs. Nontreated lambs at each site served as controls. Lamb survival from birth to weaning, at approximately 60 d, differed among sites that employed different management systems. Preweaning death losses were greater at Kansas (11.9%) than at Iowa (2.0%) or Kentucky (1.8%). Although perinatal mortality and medical attention requirements differed among lamb genetic types within a site, administration of immunoglobulin did not affect either parameter. Differences in preweaning lamb growth to 30 d of age did occur among sites (P<.01), among lamb genetic types (P<.01), and between rearing types (P<.01), but there was no effect of immunoglobulin treatment. These results indicate that a subcutaneous injection of a commercial immunoglobulin serum at birth does not improve either lamb survivability or growth performance to weaning.

Key words: lambs, survival, growth

Introduction

Lamb losses between birth and weaning may be the most serious detriments to profitability in the U. S. sheep industry. Fogarty et al. (1985) showed survival of lambs to weaning is a major factor affecting the number of lambs weaned per ewe. Similarly, Dickerson (1978) suggested efficiency of lamb production could be improved more readily by increasing the preweaning survival rate than by improving either growth rate or body composition. However, preweaning death losses are considered to be high in most parts of the world. Stamp (1967) and Dennis (1972) reported death rates ranging from 15 to 20% for most of the world's sheep producing countries. Average preweaning death loss was reported to be approximately 15% in the United Kingdom (Johnston et al., 1980) and in New Zealand (McCutcheon et al., 1981), but percentages depend on year of birth, production system, and other management factors. In Kansas, for example, Schwulst and Martin (1993) reported an average loss of 12.8% in a university flock compared with a preweaning death loss of 35.5% in a privately owned farm flock (Schoning and Sagartz, 1985).

Previous studies have failed to demonstrate a positive impact of commercially available products on lamb survival and (or) preweaning growth. For example, neither survival to weaning nor preweaning average daily gain was improved by treatment with an injectable vitamin ADE combination (Youngs and Hummel, 1992). Likewise, McClain and Morrical (1992) reported neither survival nor growth rate was increased when lambs were injected with B complex vitamins.

The objective of this project was to determine if subcutaneous injections of immunoglobulin, within 10 h of birth, would improve lamb livability and (or) preweaning growth performance of lambs of different genetic types raised in Iowa, Kansas, and Kentucky.

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Materials and Methods

Management and Data Collection. This was a collaborative project among university sheep research units at Iowa State University, Kansas State University (Colby), and the University of Kentucky. At each site, lambs were born in the fall of 1994. A total of 842 lambs (102, Iowa; 572, Kansas; 168, Kentucky) was involved. Iowa lambs were all crossbreds, lambs at Kansas included both crossbreds and purebreds, and all Kentucky lambs were purebreds. Lamb genetic types, by site, are described in Table 1.

All ewes were managed in the routine manner of the specific site with respect to vaccinations, nutrition, and general lambing time management. Data recorded on each lamb included sire breed, dam breed, dam age, gender, birth and rearing type, birth date, birth weight, and weaning weight. In addition, 30-d weights were recorded for lambs in Iowa and Kansas. The Iowa and Kentucky sites recorded medical treatments administered to lambs between birth and weaning.

Newborn lambs were weighed and ear tagged for identification within 10 h of birth at all sites. Every other single and one member of each pair of twin lambs were subjected to treatment with an immunoglobulin serum. Nontreated lambs served as controls. The dosage level for treated lambs was 10 cc of serum; 5 cc were administered subcutaneously to each side of the neck. All lambs were docked and, at Iowa and Kansas, male lambs were castrated at 7 to 10 d of age. At Kentucky, where all lambs were purebred, some male lambs were left intact.

The immunoglobulin serum contained antibodies from five organisms commonly associated with diarrhea and respiratory problems in lambs and presumably would protect them against those problems. This material, Polyserum®, was commercially prepared from blood of cattle hyperimmunized with *Corynebacterium pyogenes, Escheridhia coli, Pasteurella haemolytica, Pasteurella multocidia, and Salmonella typhimurium.*

Statistical Analyses. Survival (number

Table 1. Description of lamb genetic types by site

Lamb genetic type	Sire breed	Dam breed	No. lambs
Iowa			
I1	Suffolk	½ Polled Dorset ½ Polypay	55
I2	Suffolk	½ Romanov ½ Polled Dorset	27
I3	½ Romanov ½ Polled Dorset	½ Romanov ½ Polled Dorset	20
Kansas			
K1	Rambouillet	Rambouillet	108
K2	Polled Dorset	½ Rambouillet ½ Polled Dorset	
		½ Rambouillet ½ Finn	
		½ Rambouillet ½ Booroola Merino	122
K3	Suffolk	¾ Rambouillet ¼ Finn	
		¾ Rambouillet ¼ Booroola Merino	
		½ Polled Dorset ¼ Rambouillet ¼ Finn	
		½ Polled Dorset ¼ Rambouillet ¼ Booroola	
Merino			173
K4	Suffolk	Rambouillet sired[a]	
		Tunis sired[a]	
		Romanov sired[a]	
Katahdin sired[a]			169
Kentucky			
KY1	Polypay	Polypay	130
KY2	Polled Dorset	Polled Dorset	38

[a]Ewes born to Rambouillet or Rambouillet cross dams sired by Rambouillet, Tunis, Romanov, or Katahdin rams.

Statistical Analyses. Survival (number of lambs alive to weaning) and medical treatment data (number of lambs receiving medical treatment prior to weaning) were analyzed statistically via PROC FREQ of SAS® (SAS Institute, Inc., 1988). Individual Chi-square analyses, by site, were conducted to determine if response to immunoglobulin treatment (alive or dead at weaning for survivability and yes or no for preweaning medical treatment) was dependent on lamb genetic type and (or) rearing type.

Lamb growth data were analyzed statistically using PROC GLM of SAS® (SAS Institute, Inc., 1988). Individual analyses, by site, of actual 30-d weight, average daily gain (ADG) from birth to 30 d, weaning weight adjusted to 60 d, ADG from birth to weaning, and ADG from 30 d to weaning were conducted using models containing main effects of lamb genetic type (I1, I2, and I3 for Iowa; K1, K2, K3, and K4 for Kansas; KY1 and KY2 for Kentucky); rearing type (single, twin); gender (male, female); treatment (control, immunoglobulin serum); and all other two-way interactions. In addition, the following covariates were included: birth weight and age at 30 d for actual 30-d weight and birth weight for weaning weight adjusted to 60 d. As previously stated, weaning data were contributed by all three sites, but data at 30 d were contributed only by Iowa and Kansas.

Analyses of lamb growth traits for all three sites combined were accomplished using models similar to those described above. Modifications included the addition of site, lamb genetic type nested within site, and the interaction between treatment and lamb genetic type nested within site. Preliminary analyses indicated no interactions among any of the main effects within site; therefore, they were deleted from the final models.

Results and Discussion

Lamb Survival. One aspect of the study dealt with the effect of immunoglobulin treatment on lamb survivability, defined as the percentage of lambs born that were still alive at weaning at approximately 60 d. Survival data, by lamb genetic and rearing types, are shown in Table 2 for Iowa, Kansas, and Kentucky. The only sign of a survival difference between con-

Table 2. Lamb survival by genetic type, rearing type, and treatment[a]

Treatment No. at weaning		Control Alive	Control Dead	Control Total	Polyserum® Alive	Polyserum® Dead	Polyserum® Total
				Iowa			
Genetic type:	I1	28	2	30	25	0	25
	I2	13	0	13	14	0	14
	I3	12	0	12	8	0	8
	Total	53	2	55	47	0	47
Rearing type:	Single	20	1	21	16	0	16
	Twin	33	1	34	31	0	31
	Total	53	2	55	47	0	47
				Kansas			
Genetic type:	K1	47	7	54	44	10	54
	K2	52	8	60	55	7	62
	K3[b]	77	16	93	73	7	80
	K4	76	5	81	80	8	88
	Total	252	36	288	252	32	284
Rearing type:	Single	95	7	102	94	6	100
	Twin	157	29	186	158	26	184
	Total	252	36	288	252	32	284
				Kentucky			
Genetic type:	KY1	63	1	64	65	1	66
	KY2	19	0	19	18	1	19
	Total	82	1	83	83	2	85
Rearing type:	Single	27	1	28	29	1	30
	Twin	55	0	55	54	1	55
	Total	82	1	83	83	2	85

[a]Survival to weaning at 60 d.
[b]Survival rate difference, Control vs. Polyserum (Chi-Square; P<.10).

occurred in Kansas genetic type K3. Immunoglobulin-treated lambs in this genetic type were less likely (P<.10) to die than controls. Based on the conclusions of Young and Dickerson (1988) and Schwulst and Martin (1993), that lambs born to Booroola Merino crossbred ewes are more likely to die before weaning than those of other breed crosses, it might be surmised that immunoglobulin treatment increased survivability of the less vigorous Booroola Merino lambs (41% of the 173 lambs in K3 were born to ¼ Booroola Merino ewes). In contrast, however, 31% of the 122 lambs in the K2 genetic type were born to ½ Booroola Merino ewes, and there was no difference between immunoglobulin-treated and control lamb survival. In addition, lambing rates for the ¼ Booroola Merino ewes in K3 and ½ Booroola Merino ewes in K2 were 1.68 and 1.75, respectively, indicating response to immunoglobulin treatment was not a function of litter size. This finding disagrees with the conclusion of Notter and Copenhaver (1980) that differences in perinatal mortality between progeny of ½ Finn and ¼ Finn ewes are primarily a reflection of differences in litter size.

Overall, preweaning death losses were low in Iowa (2.0%) and Kentucky (1.8%). Within control and polyserum treatments, death losses in Iowa were 3.8% and zero, respectively. Corresponding death losses in Kentucky were 1.2 and 2.4%. Death losses in the larger and more extensively managed Kansas flock were greater (11.9%) than Iowa and Kentucky, but less than the 15 to 20% reported for most of the world's sheep producing countries (Stamp, 1967; Dennis, 1972; Rook, 1996). An earlier study with the same university flock in Kansas reported a 12.8% preweaning death loss (Schwulst and Martin, 1993). The overall death loss across genetic and rearing types was 12.0% and 10.1% for control and immunoglobulin-treated Kansas lambs.

Iowa lambs spent the first 2 to 3 d postpartum in lambing jugs. Then, they were moved to mixing pens where three to five ewes and their lambs were confined for 3 to 4 d. Thereafter, they were maintained in pens of 10 ewes until lambs were weaned. Kansas lambs were born in an open-faced shed and associated lot where as many as 200 ewes were held when the lambing season began. As soon as newborns were found, they were taken to a converted dairy barn and jugged for 2 d. The ewe and lamb families were then placed in mixing pens within an open-faced shed for another 2 d. The ewes and lambs were moved, at 4 d postpartum, to small three-sided sheds with outside lots. Thirty to thirty-three ewe-lamb families remained in each of these facilities until weaning. In Kentucky, ewes and lambs spent the first 3 d postpartum in lambing jugs. They were then returned to their original drop pens, with dirt floors bedded with wheat straw, where they remained in a group of 15 to 20 ewes with lambs until weaning. The ewes and lambs were confined to these barn pens, with access to a small outdoor area, through weaning.

The less-intensive postpartum management system may have contributed to the higher preweaning death rate at Kansas. This system probably lies somewhere

Table 3. Number of lambs within genetic type, rearing type, and treatment that received medical treatment prior to weaning

Treatment		Control			Polyserum®		
Medical treatment		No	Yes	Total	No	Yes	Total
				Iowa			
Genetic type:	I1	29	1	30	23	2	25
	I2	11	2	13	14	0	14
	I3	12	0	12	8	0	8
	Total	52	3	55	45	2	47
Rearing type:	Single[a]	18	2	20	14	2	26
	Twin	32	1	33	33	0	33
	Total	50	3	53	47	2	49
				Kentucky			
Genetic type:	KY1	52	12	64	53	13	66
	KY2	17	2	19	18	1	19
	Total	69	14	83	71	14	85
Rearing type	Single	25	3	28	23	7	30
	Twin	44	11	55	48	7	55
	Total	69	14	83	71	14	85

[a]Medical treatment difference, single vs. twin (Chi-square; P<.05)

between the intensive systems at Iowa and Kentucky and the typical shed-lambing system common in the western United States. Safford and Hoversland (1960) reported a preweaning loss of 23.5% in a shed-lambed Montana flock. Rook (1996) reported perinatal mortality typically fluctuates between 5 and 35% of Michigan's annual lamb crop.

Neither lamb genetic type nor immunoglobulin treatment had a significant effect on the number of lambs receiving medical treatment prior to weaning (Table 3). However, in Iowa, single-born lambs were more likely to receive postpartum medical treatment than were twin borns. This is in contrast to the literature, which suggests singles have higher blood serum immunoglobulin (IgG) concentrations (Gilbert et al., 1988) and greater survivability than twins from birth to weaning (Smith, 1977; Wooliams et al., 1983). Of the 4.9% of Iowa lambs receiving medical attention, most were treated for pneumonia. Rook (1996) found pneumonia to be the second largest killer, after starvation and hypothermia, of lambs from birth to weaning.

In Kentucky, 16.7% of the 168 lambs received medical treatment, almost all of which were for scours. Twenty-five of 130 KY1 lambs (Polypay) required some medical treatment (19.2%), whereas only three of the KY2 (Polled Dorset) lambs received medication (7.9%). Although lambing rates were 1.70 and 1.95 for the Polypay and Polled Dorset ewes, respectively, the average birth weight of KY1 lambs was 3.6 kg compared with 4.2 kg for the KY2 lambs. The difference in birth weights may explain why KY1 lambs required more attention than KY2 lambs, especially in light of the finding by Notter et al. (1991) that perinatal survival of lambs, sired by Suffolk rams and born to either ½ Suffolk ½ Rambouillet or ½ Suffolk ¼ Finn and ¼ Rambouillet or Polled Dorset ewes, was maximized at a birth weight of 4.4 kg. Gilbert et al. (1988) also reported serum IgG concentrations of Polypay, Rambouillet, Targhee, Columbia, Finn, and Finn cross lambs decreased linearly with decreasing birth weights.

Control single lambs in Kentucky required less medical attention than Polyserum® singles (3 vs. 7), although more control twins were medically treated than were Polyserum® twins (11 vs. 7). Overall, the number of Kentucky lambs receiving medical attention between birth and 60 d was equal for the control and Polyserum® groups.

Preweaning Growth. The second aspect of this study evaluated the effect of immunoglobulin treatment on preweaning growth of lambs. Least squares 30-d

Table 4. Least squares 30-D weight means (Kg) by genetic type and treatment within site

Site*	Genetic type**	Treatment*** Control	Polyserum®
Iowa	I1	15.1[a](28)	16.9(25)
	I2	15.2(13)	15.6(14)
	I3	14.5(12)	13.8(8)
Kansas	K1	10.9(47)	10.5(44)
	K2	12.1(52)	11.7(55)
	K3	12.1(77)	12.2(73)
	K4	12.1(76)	12.6(80)

[a]Residual SD = 2.02. Standard error of least squares means may be calculated as $(1/\sqrt{n})$ x 2.02; n (in parentheses) = number of lambs of each genetic type in each treatment within each site.
*Site difference (P<.01).
**Genetic type differences within site (P<.01).
***Treatment x genetic type within site interaction (P<.05).

Table 5. Least squares average daily gain means (Kg) from birth to 30 D by genetic type and treatment within site

Site*	Genetic type**	Treatment Control	Polyserum®
Iowa	I1	.30[a](28)	.34(25)
	I2	.29(13)	.28(14)
	I3	.27(12)	.27(8)
Kansas	K1	.22(47)	.21(44)
	K2	.25(52)	.24(55)
	K3	.26(77)	.26(73)
	K4	.26(76)	.28(80)

[a]Residual SD = .06. Standard error of least squares means may be calcu lated as $(1/\sqrt{n})$ x .06; n (in parentheses) = number of lambs of each genetic type in each treatment within each site.
*Site difference (P<.01).
**Genetic type differences within site (P<.01).

growth of lambs. Least squares 30-d weight and average daily gain means from birth to 30 d are presented by genetic type and treatment within site in Tables 4 and 5, respectively. As previously described, only Iowa and Kansas lambs were weighed at approximately 30 d. Iowa lambs weighed more (P<.01) at 30 d and gained faster (P<.01) than Kansas lambs. Suffolk-sired lambs in both Iowa (I1, I2) and Kansas (K3, K4) weighed more (P<.01) and gained faster (P<.01) than lambs sired by ½ Romanov ½ Polled Dorset Iowa rams and Rambouillet or Polled Dorset Kansas rams. Similar genetic effects were reported by Nawaz and Meyer (1992) for lambs born to Polypay, Coopworth, and crossbred ewes and sired by Suffolk rams.

A treatment x genetic type within site interaction (P<.05) was found for 30-d weight (Table 4). Genetic types I1 and I2 treated with Polyserum® weighed 1.8 and .4 kg more at 30 d than their control counterparts. Likewise, K3 and K4 lambs that received Polyserum® were slightly heavier than controls, but K1 and K2 controls weighed .4 kg more than K1 and K2 immunoglobulin-treated lambs at 30 d. Although this interaction was not statistically significant for ADG from birth to 30 d (Table 5), daily gain of lambs in the Polyserum® treatment was .04 kg/hd more than I1 controls (.34 vs. .30 kg/d). Gains of I2 and I3 Polyserum® lambs were essentially the same as controls in these genetic types. This may mean that lambs sired by Suffolk rams and born to ½ Polled Dorset ½ Polypay ewes may be more responsive to immunoglobulin administration at birth than are ½ Suffolk ¼ Romanov ¼ Polled Dorset or ½ Romanov ½ Polled Dorset lambs.

The treatment x genetic type interaction was more subtle for Kansas 30-d weight data (Table 4). When compared with differences between Iowa control and Polyserum® lamb weights, differences within Kansas genetic types were minute (.5 to .1 kg). Furthermore, the small differences between treatment 30-d weights cannot be attributed to birth weights, which were: 5.1, 5.1; 4.4, 4.4; 4.9, 4.7; and 4.9, 5.1 kg for control and Polyserum® lambs in genetic types K1, K2, K3, and K4, respectively. The inability to explain this interaction as a function of birth weight may be from the lack of a similar treatment x genetic type interaction for daily gain to 30 d, which does not include birth weight, by Kansas lambs (Table 5).

Table 6. Least squares 30-D weight and average daily gain means (Birth to 30 D) by rearing type and treatment across two sites (Iowa and Kansas)

	Treatment	
Rearing type	**Control**	**Polyserum®**
30-d wt., kg[*,**]		
Single	14.2[a,c](115)	14.8(109)
Twin	12.5(190)	12.4(190)
Average daily gain, kg[*,**]		
Single	.30[b,c](115)	.32(109)
Twin	.32(190)	.22(190)

[a]Residual SD = 2.02.
[b]Residual SD = .06.
[c]Standard error of least squares means may be calculated as $(1/\sqrt{n})$ x residual SD; n (in parentheses) = number of lambs of each rearing type in each treatment across genetic type and site.
[*]Rearing type difference (P<.01).
[**]Treatment x rearing type difference (P<.05).

Rearing type (single vs. twin) 30-d weight gain and average daily gain data were pooled for analysis across the sites of Iowa and Kansas. These results are presented in Table 6. Single-reared lambs were heavier (P<.01) at 30 d and gained faster (P<.01) than lambs reared as twins. Notter and Copenhaver (1980) reported single-reared, Suffolk-sired lambs born to ½ Finn ½ Rambouillet, ¼ Finn ¾ Rambouillet, and ½ Suffolk ½ Rambouillet ewes weighed 19% more at 45 d of age than twin-reared, Suffolk-sired lambs (19.8 vs. 16.7 kg). When 30-d weight data were analyzed for rearing type across treatment, lamb genetic type, and site (Table 6), single-reared lambs weighed 16.4% more than twins (14.5 vs. 12.5 kg). Average daily gain from birth to 30 d of the 224 singles (Table 6) was 37.8% more than the 380 twins (.31 vs. .23 kg). In contrast, Notter and Copenhaver (1980) found the difference between ADG of singles to 45 d of age to be only 16.3% more than twins.

Although immunoglobulin treatment did not directly affect 30-d weight (Table 4) or ADG from birth to 30 d (Table 5), there was a treatment x rearing type interaction (P<.05) for both 30-d weight and gain to 30 d (Table 6). Single lambs receiving Polyserum®, within 10 h of birth, tended to weigh more at 30 d (14.2 vs. 14.8 kg) and gain slightly faster (.30 vs. .32 kg/d) than controls. The magnitude of difference in twin lamb performance appeared less and the trend appeared reversed. These results allowed the finding of a statistically significant treatment x rearing type interaction, although any practical significance of the interaction is probably nil.

Least squares weaning weight means, adjusted to 60 d of age, are displayed in Table 7 by genetic type within site and treatment. Overall, Kansas lambs weighed less (P<.01) at 60 d (21.5 kg) than those produced in Iowa (24.1 kg) and Kentucky (24.4 kg). Some of this difference is attributed to the less intensive ence is attributed to the less intensive management system in Kansas. In addition, all the Kansas lambs were born to Rambouillet ewes and crosses between Rambouillet and the following breeds: Finn, Booroola Merino, Tunis, Romanov, and Katahdin (Table 1). The SID Sheep Production Handbook (1996) rates growth of lambs of these breeds from medium plus for Rambouillets to low for Booroola Merinos compared with high plus for Suffolks. Although 342 of the Kansas lambs were sired by Suffolk rams, 108 were Rambouillet-sired and 122 were Polled Dorset-sired (medium growth rate). In contrast, 80% of the Iowa lambs were Suffolk-sired and all were born to ½ Polled Dorset ewes, and Kentucky lambs were either Polypay (medium plus growth rate) or Polled Dorset purebreds.

The 55 I1 lambs, averaged across control and Polyserum® treatments, weighed 25.8 kg at weaning. This weight was heavier (P<.05) than that of I2 (23.0 kg) and the ½ Romanov ½ Polled Dorset lambs (P<.01) in the I3 genetic type. Although Romanov and Polled Dorset lambs are described as low plus and medium gainers, respectively, (SID, 1996) the limited number of observations in I3 (20; Table 4) could have contributed to some of the differences found among I1, I2, and I3 groups. In Kansas, the Rambouillet lambs in K1 and the Rambouillet, Polled Dorset, Finn, and Booroola Merino lambs in K2 weighed less (P<.01) than the Suffolk-sired lambs of K3 and K4, respectively. The overall average weaning weight, across treatment, of K1 lambs (19.8 kg) was not different from K2 (20.6 kg), nor was K2 significantly different from K3 (21.9 kg). The K4 lambs were heaviest at 60 d of age (22.7 kg). The KY1 (Polypay) and KY2 (Polled Dorset) purebred lambs raised in Kentucky weighed 24.2 and 25.2 kg, respectively, when averaged across treatments at 60 d. There was no significant treatment effect on adjusted weaning weights, across or within genetic type, at any location.

Average daily gains (Table 8) followed much the same pattern, with respect to site, genetic type within site, and treatment. The I1 lambs of Iowa gained faster (P<.01) than I2 and I3 (.35 vs. .32 and .29 kg/d, respectively). Differences between I2 and I3 were nonsignificant, probably a result of limited observations in each genetic type. In Kansas, daily gains of K4 lambs were higher than K1 (P<.01) and K2 (P<.05) lambs (.29 vs. .24 and .26 kg/hd, respectively). Daily gains of K3 were greater (P<.05) than K2. The K3 and K4 daily gains were similar (.28 vs. .29 kg/hd), as were K1 and K2. Differences in daily gains of Kentucky lambs (KY1 vs. KY2) were nonsignificant. No Polyserum® treatment differences were found for any genetic type within any location.

The effect of rearing type across the three sites, genetic types, and treatment is presented in Table 9. Single lambs weighed 23% more (P<.01) at weaning and gained 25% faster (P<.01) than twins from birth to weaning. There was no effect of immunoglobulin treatment at birth on either weaning weight or daily gain from birth to weaning.

Table 10 shows the average daily gains of singles and twins from 30 d to weaning at 60 d. These data were pooled across Iowa and Kansas sites and across genetic types. Both control and immunoglobulin single lambs gained faster (P<.01) than their twin counterparts. There was no effect of immunoglobulin treatment in either rearing type.

The results of this study point to the differences in survivability of lambs born into different management systems, regardless of the genetic type. Within a management system, perinatal mortality may differ among genetic types because of differences in litter size, which is negatively related to lamb birth weight. Lambs that weigh less at birth may also require more medical attention early in life than heavier lambs. However, the administration of a commercial immunoglobulin at birth did not affect mortality rates or medical attention requirements.

Preweaning lamb growth to 30 d of age was influenced by the genetic types used

Table 7. Least squares weaning weight means (Kg), adjusted to 60-D, by genetic type and treatment within site

Site*	Genetic type**	Treatment: Control	Treatment: Polyserum®
Iowa	I1	25.2[a](28)	26.4(25)
	I2	23.6(13)	22.5(14)
	I3	20.9(12)	20.8 (8)
Kansas	K1	19.9(47)	19.7(44)
	K2	21.2(52)	20.1(55)
	K3	21.7(77)	22.0(73)
	K4	22.0(76)	23.4(80)
Kentucky	KY1	24.3(63)	24.0(65)
	KY2	25.2(19)	25.3(18)

[a]Residual SD = 4.08. Standard error of least squares means may be calculated as $(1/\sqrt{n}) \times 4.08$; n (in parentheses) = number of lambs of each genetic type in each treatment within each site.
*Site difference (P<.01).
**Genetic type differences within site (P<.01).

in this study. Further, response to immunoglobulin treatment at birth may depend on the lamb's genetic makeup. However, this response could not be explained as a function of birth weight, which in turn, is a function of litter size. Although weaning weights at 60 d were affected by both genetic and rearing type, there was no effect of immunoglobulin treatment.

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Table 8. Least squares average daily gain means (Kg) from birth to weaning (60 D) by genetic type and treatment within site

Site*	Genetic type**	Treatment: Control	Polyserum®
Iowa	I1	.34[a](28)	.36(25)
	I2	.33(13)	.31(14)
	I3	.29(12)	.29(8)
Kansas	K1	.24(47)	.24(44)
	K2	.27(52)	.25(55)
	K3	.28(77)	.28(73)
	K4	.28(76)	.30(80)
Kentucky	KY1	.34(63)	.34(65)
	KY2	.34(19)	.34(18)

[a]Residual SD = .06. Standard error of least squares means may be calcu lated as $(1/\sqrt{n})$ x .06; n (in parentheses) = number of lambs of each genetic type in each treatment within each site.
*Site difference (P<.01).
**Genetic type differences within site (P<.01).

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Table 9. Least squares weaning weight, adjusted to 60 D, and average daily gain means (Birth to 60 D) by rearing type and treatment across sites

	Treatment	
Rearing type	Control	Polyserum®
60-d wt., kg*		
Single	25.2[a,c](142)	25.7(138)
Twin	20.9(245)	20.4(244)
Average daily gain, kg*		
Single	.34[b,c](142)	.35(138)
Twin	.28(245)	.27(244)

[a]Residual SD = 4.08.
[b]Residual SD = .06.
[c]Standard error of least squares means may be calculated as $(1/\sqrt{n})$ x residual SD; n (in parentheses) = number of lambs of each rearing type in each treatment across genetic type and site.
*Rearing type difference (P<.01).

Table 10. Least squares aAverage dDaily gain means (Kg) from 30 D to weaning (60 D) rearing type and treatment[a]

	Treatment	
Rearing type*	Control	Polyserum®
Single	.33[b](115)	.33(109)
Twin	.28(190)	.27(190)

[a]Includes only Iowa and Kansas data.
[b]Residual SD = .08. Standard error of least squares means may be calculated as $(1/\sqrt{n})$ x residual SD; n (in parentheses) = number of lambs of each rearing type in each treatment across genetic type and site.
[d]Rearing type difference (P<.01).

Effect of Extended Light on Growth and Reproductive Performance of Crossbred Ewe Lambs Exposed For Fall Lambing[1]

D. J. Hanson[2] and A. L. Slyter[3]

Summary

A series of three trials were conducted over a 3-year period evaluating the effect of artificially extending the length of light exposure in mid-winter on weight gain and reproductive performance of April-born crossbred ewe lambs exposed to rams at 12 to 13 mo of age. Ewe lambs that were exposed to extended light gained more weight (PW .06), were heavier at mating time in Trials 1 and 3 (PW.03), had a higher lambing percentage ($P = .12$, Trial 1; $P < .05$, Trials 2 and 3), and in Trial 3 gave birth to more lambs per ewe lambing ($P = .05$). A higher percentage of 1/4 Finnsheep, 1/4 Dorset, 1/2 Targhee (FDT) cross ewe lambs lambed as compared to 1/2 Hampshire, 1/8 Finnsheep, 1/8 Dorset, 1/4 Targhee (HFDT) cross ewe lambs. Timing and length of light exposure (Trial 1 vs Trials 2 and 3) were important, although they can not be conclusively separated from year effects. Based on this study, light treatment is an effective method to improve weight gains and reproductive performance of maiden ewe lambs exposed for fall lambing.

Key Words: ewe lambs, puberty, season, growth, reproduction

Introduction

The key events leading to sexual maturity will occur only when internal and external cues indicate that body weight (of the animal) and season are favorable for the initiation of puberty. Foster (1994) reported that lambs that were well fed from birth grew rapidly and reached puberty at the normal age (30 wk), whereas lambs that were placed on restricted diets after weaning had delayed onset of puberty.

Photoperiod is an important factor regulating the onset of puberty in sheep. A sequence of photoperiod signals of long days followed by short days is required for puberty in ewe lambs to occur at the normal time (Foster, 1994). The timing of the administration of various light treatments has a major influence on the timing of subsequent reproductive activity (Yellon and Foster, 1985). Exposure to a long photoperiod has also been shown to be stimulatory to growth in lambs (Forbes et al., 1981; Schanbacher and Crouse, 1980).

The objective of the following research was to study the effect of extended photoperiod during mid-winter on growth and reproductive performance of April-born crossbred ewe lambs exposed for fall lambing.

Materials and Methods

Trial 1

One hundred ninety-two crossbred ewe lambs (146 FDT cross, 46 HFDT cross) were utilized in Trial 1 in a 2x2 factorial arrangement. These ewes were born in April 1992 at the Antelope Range Livestock Research Station, Buffalo, SD (45.39 °N Latitude). They were weaned and moved to the SDSU Sheep Teaching and Research Unit in Brookings, SD (44.20 ° N Latitude), September 25, 1992.

Ewes were randomly assigned within breed group to either the natural ambient photoperiod (C) ≅10 h or extended light (EL) 16 h from January 4, 1993, to February 19, 1993. Ewes in the treated group (EL) were exposed to artificial light (16.5 ft candles at ewe eye level) from 1700 to 2300 daily for a total of approximately 16 h of light per 24 h. Ewes were co-mingled and managed as a single group throughout the trial except for the 46 d during artificial light treatment. Ewes were limit fed a ration of 20% rolled corn, 20% oats, 20% corn silage, and 40% alfalfa hay (as fed, wet basis). They also had access to a mixture of 50% white salt and 50% dicalcium phosphate free-choice. Extended light ewes were kept in a dirt lot

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with access to a 12.5 x 11.5 M open front shed. Water was provided by automatic bowl fountains. Artificial light was provided by four 500-watt halogen lamps that were located approximately 2 M from eye level of the ewes. Extended light ewes were locked in the shed from 1700 to 800 daily during treatment. Control ewes were also kept in a dirt lot and had access to an unlighted open front shed of similar size.

Starting April 1, 1993, the ewes were exposed to three epididymectomized teaser rams for 14 d. Four intact Hampshire rams (nonlight treated) replaced the teasers April 15 for a 35-d breeding season. These rams were subjected to a breeding soundness exam that evaluated structural soundness, testicle shape, size and tone, as well as semen quality. Rams were collected using a SPE Electro Ejaculator and semen evaluated for motility and concentration using the hanging drop technique.

Body weights were recorded on all ewes September 29, 1992, which represented their weaning weight, and on April 6, 1993, prior to the breeding season.

Trial 2

One hundred seventy-six FDT and 37 HFDT ewe lambs were randomly assigned within breed groups to one of two treatment groups in a 2 2 factorial arrangement. Ewes were treated the same as in Trial 1 except the treatment groups were exposed to either natural day length (C) or extended light (EL) of 18 h of light and 6 h of dark. This light treatment began December 1, 1993, and was discontinued February 10, 1994. Artificial light provided an average of 18 ft candles of light at ewe eye level.

Body weight was recorded on all ewes September 29, 1993, which represented their weaning weight, and March 29, 1994, a weight taken just prior to the breeding season. Five intact Finn-Dorset x Targhee rams were used in place of intact Hampshire rams.

Trial 3

In this study 208 FDT cross ewe lambs were randomly assigned to either a natural ambient photoperiod (C) or an extended light exposure (EL) group in a completely randomized design.

Ewes were treated and handled in the same manner as for Trial 2 except body weights were recorded on all ewes October 10, 1994, and March 16, 1995, prior to the breeding season.

Ewes were shed lambed in a semi-confinement lambing system. Lambing date and number, sex, and birth weight of lambs were recorded as ewes lambed and were placed in individual jugs.

Statistical analysis was performed on normally distributed data by the GLM procedure of SAS (SAS, 1988). Continuous traits were analyzed by least squares procedures. Discrete effects included in the model were treatment (EL vs C) breed (FDT vs HFDT) and the interaction of treatment breed. Chi square procedures were used to evaluate percentage of ewes lambing.

Results

Least squares means and standard errors along with probability levels are shown in Table 1 for weight parameters and number of lambs born per ewe lambing. Breed treatment interaction means are presented since breed response level was different in several cases. Lambing percentage means and chi square probabilities are also shown in Table 1.

Trial 1

Initial weights (Table 1) for extended light (EL) and control (C) ewes were similar ($P = .71$). Overall weight gain and final weight was greater ($P < .03$) for EL ewes than for C ewes. Examination of the interaction means revealed that HFDT ewes on EL gained more weight than FDT ewes. Eight percent of the EL ewes lambed compared to 3% of the C ewes ($P = .12$). Although not significant, no doubt due to the small total number responding, a higher percentage of FDT ewes lambed in both the C and EL groups than HFDT ewes. Number of lambs born per ewe lambing numerically favored the EL group ($P = .26$).

Trial 2

Initial weight (Table 1) was similar between C and EL groups and between breeds. HFDT ewes exposed to EL gained more weight ($P = .08$) during the trial than HFDT C ewes. Final weight of HFDT ewes was heavier ($P < .01$) than FDT ewes (70.4 ñ 1.2 vs 66.8 ñ .57 kg, respectively). More ($P < .01$) EL ewes lambed than C ewes, with FDT ewes being superior to HFDT ewes. None of the HFDT control ewes lambed compared to 31.8% of the FDT control ewes. Lambs born per ewe lambing did not differ between treatments or breeds.

Trial 3

Trial 3 contained only FDT ewes. Initial weight of C and EL ewes was similar (Table 1). Ewes on EL gained 2.0 kg ($P < .01$) more weight during the trial and were 2.4 kg heavier when the final weight was taken. More ($P < .01$) EL ewes lambed than C ewes (83.8 vs 57.3%, respectively). In addition, the number of lambs born per ewe lambing was .16 lamb higher ($P = .05$) for EL ewes than control ewes.

Discussion

Trials were not combined in the analyses because of differences in protocol. In Trial 1, light treatment was from January 4 to February 19 and used a 16L:8D sequence. In Trials 2 and 3, treatment was 18L:6D running from December 1 to February 10. Trials 1 and 2 included two breed groups (FDT and HFDT), while Trial 3 had only FDT ewes. In general, HFDT ewe lambs gained more weight and were heavier at breeding time than FDT ewes. This would indicate a possible later growth curve for the larger framed Hampshire cross lambs due to the Hampshire terminal sire influence. Although they were heavier, a lower percentage of the HFDT ewes lambed than did FDT ewes. Weight has been shown to be an important factor that influences the occurrence of puberty (Foster, 1994). The higher weight gain of the Hampshire cross lambs would indicate that they were later maturing and thus may not have reached sufficient weight to achieve puberty, or this may simply reflect breed differences in out of season conception success. Higher weight gain of EL treated animals in this study is supported by work by Schanbacher and Crouse (1980) and Forbes et al. (1981) who noted that lambs grew more rapidly when exposed to long-day photoperiod. However, in a study by Schwulst and Minton (1991), supplemental lighting was ineffective in improving average daily gain. Additional work is merited to substantiate or refute the effect of extended photoperiod on growth.

Photoperiod also has a role in the timing of puberty. Long days have been shown to inhibit puberty in some species. Long days followed by short days appear needed for the initiation of puberty in sheep. However, photoperiodic timing is more complex than the mere experience of short days (Foster, 1994). The findings of a long-day requirement to begin ovulation in a young short-day breeder raises the possibility that sheep maintain a "photoperiod history." Ewe lambs may need to experience a shift from long to short day prior to reaching puberty. This was accomplished in this study by increasing light exposure in December until February, thus creating an artificial shift from long to short days. Ewe lambs were 8 mo old at this time and at a weight puberty should be attained.

The effect of EL on the percentage of ewes exposed that lambed improved from Trial 1 through Trial 3. The higher percentage lambing in Trial 2 compared to Trial 1 can be attributed to the earlier starting date (December 1 vs January 4) and(or) longer daily light (18 vs 16 h) in Trial 2. The success rate (83.8% lambing) observed in Trial 3 for FDT ewes is not attributable to any change in EL protocol. Thus, this increase is unexplained. Within the FDT breed group, a corresponding increase in response was also observed for C ewes from Trial 1 to Trial 3. Because C and EL ewes were exposed as a single group to remove sire effects, co-mingling may have stimulated estrous activity among the C ewes. Thus, greater estrous activity in EL ewes may have stimulated more C ewes to cycle in Trials 2 and 3.

The lambing response was higher for FDT than for HFDT ewes in both Trials 1 and 2. Dickerson and Laster (1975) found Finnsheep crosses superior in reaching puberty compared to seven pure breeds including Hampshire. Thus, the higher percentage of Finnsheep in the FDT ewes may account for the greater response in percentage lambing. Treatment with EL in Trial 3 not only increased the percentage that lambed but also increased the number of lambs born per ewe lambing.

Conclusions

Extending the daily photoperiod during mid-winter increased weight gain and fall lambing performance of April-born crossbred ewe lambs. Response differences were noted between breed of ewe, trial, and(or) year. These data suggest that a rather simple photoperiod treatment can improve weight gain and achieve successful out-of-season lambing in FDT cross ewe lambs. By taking advantage of out-of-season lambing, producers should be able to increase profitability of sheep production.

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Yellon, S. M., and D. L. Foster. 1985. Alternate photoperiods time puberty in the female lamb. Endocrinology 116:2090-2097.Table 1. Effect of extended light on weight and reproductive performanceof crossbred ewe lambs

Table 1. Effect of extended light on weight and reproductive performance of crossbred ewe lambs

	Trial 1[a]			Trial 2[b]			Trial 3[c]		
Item	C	EL	P*	C	EL	P	C	EL	P
Initial weight, kg									
FDT[e]	(73)[d]	(73)		(85)	(86)		(103)	(105)	
	35.3 ± .63	36.5 ± .64	.16	41.9 ± .72	43.1 ± .72	.26	38.7 ± .57	39.1 ± .56	.61
HFDT[f]	(23)	(23)		(19)	(18)				
	34.3 ± 1.11	33.7 ± 1.16	.72	43.1 ± 1.56	39.9 ± 1.52	.14	–	–	–
Pooled	(96)	(96)		(104)	(104)		(103)	(105)	
	34.7 ± .64	35.1 ± .67	.71	42.2 ± .85	41.4 ± .85	.50	38.7 ± .57	39.1 ± .56	.61
Overall weight gain, kg				**					
FDT	25.6 ± .69	26.8 ± .70	.19	24.4 ± .61	24.2 ± .61	.79	27.1 ± .45	29.1 ± .44	<.01
HFDT	26.2 ± 1.02	29.7 ± 1.06	.02	26.8 ± 1.33	30.9 ± 1.29	.08	–	–	–
Pooled	25.9 ± .67	28.2 ± .70	.02	26.6 ± .53	27.5 ± .71	.06	27.1 ± .45	29.1 ± .44	<.01
Final weight, kg									
FDT	60.8 ± .86	63.4 ± .89	.04	66.4 ± .80	67.3 ± .81	.41	65.8 ± .74	68.2 ± .73	.02
HFDT	60.5 ± 1.26	63.2 ± 1.32	.14	70.0 ± 1.76	70.8 ± 1.71	.74	–	–	–
Pooled	60.6 ± .84	63.3 ± .88	.03	68.2 ± .96	69.0 ± .94	.51	65.8 ± .74	68.2 ± .73	.02
Lambing percentage									
FDT	4.0	9.9	.16	31.8	57.5	<.01	57.3	83.8	<.01
HFDT	0.0	4.5	.29	0.0	36.8	<.01	–	–	–
Pooled	3.1	8.3	.12	27.9	54.8	<.01	57.3	83.8	<.01
No. of lambs/ewe lambing									
FDT	1.00 ± .27	1.42 ± .17	.22	1.18 ± .06	1.08 ± .05	.20	1.20 ± .06	1.36 ± .05	.05
HFDT	.0	1.00	NA	.0	1.14 ± .14	NA	–	–	-
Pooled	1.00 ± .26	1.38 ± .16	.26	1.21 ± .09	1.11 ± .07	.20	1.20 ± .06	1.36 ± .05	

[a]C = control, ambient photoperiod; EL = extended photoperiod of 16L:8D from January 4, 1993, to February 19, 1993.
[b]C = control, ambient photoperiod; EL = extended photoperiod of 18L:6D from December 1, 1993, to February 10, 1994.
[c]C = control, ambient photoperiod; EL = extended photoperiod of 18L:6D from December 1, 1994, to February 10, 1995.
[d]Number in parenthesis is the number of animals.
[e]FDT = Finn-Dorset-Targhee.
[f]HFDT = Hampshire ´ FDT.
*The P-value for mean comparisons within trial.
**Significant interaction for breed ´ treatment (P £ .05).

Comparisons of Wool and Skin Parameters Between Merino Crossbred and Rambouillet Yearling Ewes

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Summary

Wool side samples and skin sections were collected in two consecutive years from one hundred ninety, eleven-month-old ewes. Ewes consisted of 116 Rambouillet-Merino (RM) crossbred ewes sired by Merino rams and 74 Rambouillet (R) yearling ewes. Ewes were maintained under similar environmental conditions. Data collected included type of birth/rearing, staple length, clean fleece weight (CFW), fiber diameter (FD), number of secondary follicles per mm^2 (Ns), number of primary follicles per mm^2 (Np), total follicles per mm^2 (Ns+p), and secondary to primary ratios (S/P ratios). Birth/rearing type had an effect on CFW ($P < 0.001$) and S/P ratio ($P < 0.001$). Ewes born and raised as twins produced less pounds of clean wool and had fewer secondary follicles than ewes born single. Staple length differed ($P < 0.001$) between RM ewes and R ewes (8.02 vs 7.10 cm, respectively). Year * breed interaction affected CFW ($P = .045$) with RM ewes having higher CFW than R ewes in both years. Fiber diameter was finer ($P < 0.05$) for RM (17.58 ± 0.13 µm) than for R ewes (18.21 ± 0.22 µm). Number of secondary follicles was greater ($P < 0.001$) in RM ewes than R ewes (54.5 ± 1.42 vs 39.8 ± 2.32, respectively). Number of primary follicles was not different ($P > 0.05$). Secondary to primary ratios were 20.6 ± 0.38 for RM ewes and 15.9 ± 0.62 for R ewes ($P < 0.001$). Individual sires within each breed had an effect on secondary follicle numbers, staple length, fiber diameter, and coefficient of variation of fiber diameter.

Key Words: wool production, wool follicles, S/P Ratio, Rambouillet, Merino, twins

Introduction

Most research to evaluate genetic gains for wool production has been conducted in Australia. Little research has been undertaken to determine if the United States can import genetically superior rams for wool production from Australia to improve both quantity and quality of wool produced. Clean fleece weight is affected by skin area, mean fiber diameter, fiber length, and number of active follicles per unit area of skin (Bosman, 1933). Merinos have been noted for their high fiber production due to high follicle density, staple length and increased skin surface area (Carter and Clarke, 1957).

Merinos show greater follicle density compared to other breeds due to increased maturation of secondary follicles (Carter and Clarke, 1957). Secondary to primary (S/P) ratios in Merino sheep range from a low of 11:1 to a high of 48:1, with an average ratio of 20:1 (Nay, 1972). British breeds, such as the Romney, have S/P ratios of 6:1 while Longwool-Merino crossbreds have S/P ratios of 13:1 (Nay, 1972; Fraser and Short, 1960). Thomas and co-workers (1993) reported S/P ratios in Targhee lambs of 10.6:1.

Conflicting data involving S/P ratios exist when comparing multiple-versus single-born lambs. Thomas and co-workers (1993) found no effect of type of birth/rearing on follicle density or S/P ratios ($P > 0.10$) for Targhee sheep. Meikle and others (1988) removed skin sections from 637 Romney-Merino ewes and found type of birth/rearing had no effect on follicle density, S/P ratios or grease fleece weight. In contrast, Butler (1981) conducted a study using 22 male and female Corriedale sheep, age 14 mo, classified as being born/reared single or twin. In that study, multiple-born sheep had an 8.6% lower S/P ratio than single-born sheep. Brown and co-workers (1966) also observed a 0.21 pound decrease in clean wool production in multiple-born ewes compared to single born ewes.

This study was initiated to determine if

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clean wool production, fiber diameter, and follicle density could be improved by using Australian Merino rams on a foundation Rambouillet flock. The effects of birth and rearing types on wool traits were also evaluated.

Materials and Methods

In the first year of the study, wool and skin samples were analyzed from 98 Rambouillet-Merino (RM) crossbred yearling ewes and 28 Rambouillet (R) yearling ewes. All ewes were progeny from Rambouillet ewes bred to seven Merino or two Rambouillet sires. The second year's samples were collected from 78 RM yearling ewes and 19 R yearling ewes. These ewes were produced from R ewes bred to either 5 Merino or 2 Rambouillet sires, all of which had been used in the previous year. All ewes were maintained as a single group under similar environmental conditions. Data collected included type of birth/rearing, staple length, and clean fleece weight (CFW). Staple length (SL) was measured by removing locks from the site where the skin sections would be removed and measuring the locks with a ruler to the nearest 5 mm (ASTMa, 1996). Clean fleece weight was obtained by taking a side sample and determing its' yield (ASTMb, 1996), subsequently multiplying the grease fleece weight by the yield of the side sample.

Skin sections were collected and processed according to procedures outlined in Maddocks and Jackson (1988) using a 1 cm trephine. Animals were restrained in a recumbent position and skin sections removed from the mid-side over the third thoracic rib between the midline of the back and the midline of the abdomen, with care being taken that the skin was in a fully relaxed unstretched position before trephining.

Skin sections were fixed in a 10% buffered formalin solution and processed using conventional histological procedures. Sections (5 mm thick) were cut parallel to the skin surface, 35-60 mm in depth, the approximate level of the sebaceous gland. Skin sections were stained with hematoxylin, eosin, and picric acid (Maddocks and Jackson, 1988). Primary follicles were identified by the presence of a sweat duct and the erector muscle (Moore et al., 1989).

Number of secondary follicles (Ns), number of primary follicles (Np), total follicles (Ns +Np), secondary to primary ratios (S/P) and density (total follicles per mm^2) were determined using Optimas, the Optimas Corporations image analysis program. Measurement of eight fields is standard (Moore, 1989). The camera used in this study to grab the images did not use square pixels, thus only a 1 mm x 0.8 mm field could be displayed on the computer screen. To achieve a total of 8 mm^2, 10 fields were counted. Counting boundaries were drawn by Optimas after identification of primary and secondary follicles. Primary and secondary follicles which crossed the left-hand and top margins of the box were included in the count. Those follicles which crossed the bottom and right-hand boundaries were

Table 1. Least squares means and standard errors for fleece characteristics.

			Parameters[a]		
Source	No.	CFW, kg	SL, cm	FD, μm	FDCV, %
Year					
1992	116	3.00±0.06	6.63±0.13[c]	17.41±0.14[c]	17.47±0.28
1993	74	3.04±0.09	8.49±0.17[b]	18.37±0.22[b]	17.46±0.42
Breed					
RM[a]	145	3.50±0.06[b]	8.02±0.10[b]	17.58±0.13[c]	17.75±0.26
R[a]	45	2.55±0.10[c]	7.10±0.10[c]	18.21±0.22[b]	17.18±0.42
Rearing					
Single	84	3.23±0.07[b]	7.63±0.13	17.68±0.17	17.22±0.33
Multiple	106	2.81±0.07[c]	7.49±0.13	18.11±0.17	17.71±0.33

[a]RM = Rambouillet-Merino cross ewes; R = Rambouillet ewes; CWF = clean fleece weight; SL = staple length; FD = fiber diameter; FDCV = fiber diameter coefficient of variation.

[b,c]Means in the same column with different superscripts differ ($P < 0.05$).

excluded (Maddocks and Jackson, 1988). The whole sample count was then divided by sample area to obtain density. Data were analyzed and reported as representing a mm^2 skin section (Maddocks and Jackson, 1988). Sirolan-Laserscan was used to measure fiber diameter (FD) of the side samples of wool (IWTO, 1993). All data were analyzed using general linear model procedures (GLM) for analysis of variance with means seperated by least square differences (LSD) when a significant F-test was determined (SAS, 1992)

Results and Discussion

Fleece characteristics are shown in Table 1. No differences ($P < 0.05$) were observed between years when comparing CFW, however, there were differences between years in staple length and fiber diameter ($P < 0.05$). Staple length was nearly 2 cm longer in 1993 than 1992, correspondingly, the diameter of the fibers was larger in 1993 than 1992. Year differences are expected due to the varying availability of feed stuffs and environmental conditions. Differences between breed ($P < 0.05$) were apparent in CFW, staple length and fiber diameter during the study. Snowder *et al.*, (1998) reported similar findings for fine wool Merino-Rambouillet crosses and strong wool Merino-Rambouillet crosses when compared to straight-bred Rambouillet. A year-by-breed interaction was present for CFW. Overall, Rambouillet-Merino crossbred ewes produced considerably more clean wool than R ewes. Snowder *et al.*, (1998) reported similiar findings. However RM ewes produced more wool in 1992 than 1993, whereas R ewes had a greater CFW in 1993 compared to 1992. Rambouillet-Merino cross ewes had longer SL than Rambouillet ewes. The increased staple length has an additive effect on CFW. Williams and Winston (1987) reported ewes selected for heavier fleece weights had a longer staple length than those selected for decreased fleece weights. There is the possibility that the ewes sampled in 1993 were subject to less stress due to environment than ewes sampled in 1992. Clean fleece weights were higher ($P < 0.05$) for single-reared lambs than for multiple-reared lambs, with no differences in staple length or fiber diameter, due to an increased number of mature secondary follicles producing fiber and/or greater skin surface area. Clean fleece weight was influenced by type of rearing and by year-by-breed interaction. These results are similar to values reported by Brown and coworkers (1966). The cause of this decrease in CFW by multiple-reared ewes could be due to prenatal competition of fetuses for nutrients, resulting in a decrease in secondary follicle development. Nutrition after birth also plays an important role in the number of secondary follicles that subsequently mature and produce fiber (Table 2). Schinckel and Short (1961) reported that nutritional stress post-natally can decrease wool production as adults. Also, multiple-born lambs tend to be smaller and have less surface area. Thomas et al. (1993) reported positive correlations between lamb weaning weight and yearling fleece weight ($P < 0.003$).

Table 2 provides data for follicle populations. Year differences exist for Ns and N(p+s) per mm^2. Breed also had an affect

Table 2. Least squares means and standard errors for follicle populations.

Source	No.	Parameters[a]			
		Ns per mm^2	Np per mm^2	N(p+s) per mm^2	S/P ratio
Year					
1992	116	50.4±1.54[b]	2.7±0.15	53.2±1.64[b]	17.8±0.41
1993	74	43.9±2.30[c]	1.2±0.20	46.4±2.44[c]	18.6±0.62
Breed					
RM[a]	145	54.5±1.42[b]	2.6±0.21	57.1±1.51[b]	20.6±0.38[b]
R[a]	45	39.8±2.32[c]	2.4±0.25	42.4±2.47[c]	15.9±0.62[c]
Rearing					
Single	84	49.5±1.80[b]	2.4±0.18	52.1±1.92	19.4±0.48[b]
Multiple	106	44.9±1.81[c]	2.5±0.17	47.5±1.92	17.0±0.48[c]

[a]RM = Rambouillet-Merino cross ewes, R = Rambouillet ewes; Ns = number of secondary follicles; Np = number of primary follicles; N(p+s) = total follicle population; S/P ratio = secondary to primary follicle ratio.
[b,c]Means in the same column with different superscripts differ ($P < 0.05$).

on Ns, N(p+s) and S/P ratio ($P < 0.05$) with RM ewes having greater numbers of secondary follicles, total follicles and having a higher S/P ratio. Type of rearing affected S/P ratio, with single reared lambs having a higher ratio than multiple reared lambs ($P < 0.05$). Rambouillet-Merino ewes had higher follicle density and S/P ratios, compared to Rambouillet ewes. Breed and year had an effect on follicle numbers. Rambouillet-Merino cross ewes had higher Ns, N(p+s), and S/P ratio compared to R ewes in both years (year 1; 56.0 v 44.8: 58.5 v 47.8: 20.3:1 v 15.3:1: year 2; 53.0 v 34.8: 55.8 v 37.1: 20.8:1 v 16.4:1, respectively). Meikle and coworkers (1988) reported that S/P ratios increased with the introduction of Merino genetics, primarily due to increased numbers of secondary follicles. Primary follicle populations were not different ($P > 0.05$) between RM or R ewes. Carter (1955) reported similar results in that primary follicle numbers vary little among breeds, with secondary follicle numbers varying. Schinckel and Short (1961) reported the primary effect of decreased prenatal nutrition is a decreased total follicle population.

Year had an effect on Ns and N(p+s) but not on Np or S/P ratio. Type of rearing affected Ns and S/P ratio with single-born ewes having more Ns than multiple-born (49.5 v 44.9) and a higher S/P ratio(19.4 v 17.0). Animals born and reared differently may be affected by a maternal handicap which decreases number of follicles formed prenatally. Schinckel (1955) reported twins had a lower S/P ratio than single lambs. He theorized that multiple-born lambs were subject to some nutritional penalty. Butler (1981) reported that the effect of birth status on S/P ratio appears to be primarily due to an 8% (not significant) increase in secondary follicle density. Butler's study found follicle density similar for single and multiple-born lambs. This research project did not indicate any differences in Np follicles between breeds. Other research has not observed differences between multiple-born or single-born lambs (Abouheif, 1980; Thomas 1993), which may reflect differences in nutritional status and breeds between the studies.

The role that sires play in the genetic process cannot be emphasized enough. With the limited number of Merino sires (7) and Rambouillet sires (2), differences ($P < 0.05$) among sires were quite evident in their offspring in fiber diameter, staple length, S/P ratios, Ns, Np, and N(p+s) (Table 3). To make real progress in economic traits, such as wool, these traits must be identified (clean fleece production, fiber diameter, and staple length) and measured, allowing more accurate selection of superior individuals.

Further research is needed to determine the effects of selecting animals on the basis of wool characteristics and the subsequent effects on other economically

Table 3. Least squares means and standard errors for fleece characteristics of ewes sired by Merino and Rambouillet rams.

			Parameters*		
Source	No.	FD	CFW	FDCV	SL
Merino					
4	28	17.40 ± 0.24^{c}	3.52 ± 0.10^{a}	15.8 ± 0.46^{c}	8.4 ± 0.18^{a}
10	31	17.43 ± 0.23^{c}	3.52 ± 0.10^{a}	18.6 ± 0.45^{a}	$7.6 \pm .0.18^{bcd}$
23	8	17.19 ± 0.46^{c}	3.61 ± 0.20^{a}	18.1 ± 0.89^{abc}	$7.7 \pm 0.35b^{abcd}$
27	25	17.51 ± 0.25^{bc}	3.60 ± 0.11^{a}	18.6 ± 0.49^{a}	8.4 ± 0.20^{a}
40	24	18.18 ± 0.26^{ab}	3.58 ± 0.11^{a}	17.8 ± 0.50^{abc}	7.6 ± 0.20^{bcd}
61	23	17.12 ± 0.26^{c}	3.56 ± 0.11^{a}	17.0 ± 0.51^{bc}	8.2 ± 0.20^{ab}
316	6	18.24 ± 0.53^{abc}	3.10 ± 0.23^{a}	18.3 ± 1.03^{ab}	8.2 ± 0.43^{abc}
Rambouillet					
435	15	17.76 ± 0.40^{abc}	2.47 ± 0.17^{c}	16.3 ± 0.78^{abc}	7.2 ± 0.33^{cd}
280	30	18.66 ± 0.23^{a}	2.63 ± 0.10^{bc}	18.0 ± 0.46^{abc}	7.0 ± 0.20^{d}

*FD = Fiber diameter; CFW = clean fleece weight; FDCV = fiber diameter coefficient of variation; SL = staple length.
[a,b,c,d]Means in the same column with different superscripts differ ($P < 0.05$).

important traits such as lamb production and growth rate. Snowder *et al.*, (1998b, 1998c) found that progeny of strong-wool and fine-wool Merino-Rambouillet crosses grew slower, and had less desirable carcass characteristics when compared to progeny of straight-bred Rambouillet. Care must be taken when selecting only for a specific trait, for example small negative correlations exist between fleece traits and carcass composition. Fleece weight and staple length are negatively related to meatiness (Scott, 1970) and wool only partially contributes to the economic return of the sheep industry.

Implications

The present research demonstrates that the introduction of genetically different sires can alter the quality and quantity of wool production in a single generation. Ewes sired by Merino rams produced more and finer wool which had longer staple length than purebred Rambouillets. Also, the RM ewes had higher S/P ratios and follicle populations than R ewes, both of which contribute to increased wool production. All these factors could contribute to increased total return for producers, and an increase in revenue if they can be achieved without decreases in reproductive rate, lamb growth rate, and carcass characteristics. Caution should be taken when implying that Merino influence will improve the Rambouillet population, as there were limitations in this study due to low representation of Rambouillet sires. Also, due to the limited number of Rambouillet sires, heritabilities were not calculated. Research by Snowder *et al.*, (1998a,b,c) shows that wool production can be increased significantly but that differences in progeny growth rate and carcass characteristics are evident. More research needs to be conducted in this area comparing different strains of Merino versus Rambouillet and other domestic sires to determine how much progress can be obtained from introducing Merino rams into U.S. flocks.

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Table 4. Least squares means and standard errors for follicle characteristics of ewes sired by Merino and Rambouillet rams.

		Parameters*			
Source	No.	Ns	Np	N(p+s)	S/P RATIO
Merino					
4	28	56.2±2.53[ab]	2.0±0.11	58.7±2.69[ab]	22.7±0.68[a]
10	31	60.7±2.48[a]	2.2±0.11	62.1±2.64[a]	21.0±0.67[ab]
23	8	57.1±4.87[ab]	2.3±0.21	60.8±5.17[ab]	20.3±1.30[bc]
27	25	55.3±2.68[ab]	2.3±0.12	58.4±2.85[ab]	18.8±0.72[cd]
40	24	50.9±2.75[b]	2.0±0.12	53.5±2.93[b]	20.6±0.74[bc]
61	23	50.7±2.80[b]	1.9±0.12	53.2±2.97[bc]	21.5±0.75[ab]
316	6	50.1±5.64[bc]	2.1±0.24	53.4±5.99[bc]	19.0±1.51[bcd]
Rambouillet					
435	15	37.0±4.28[c]	1.8±0.19	39.4±4.55[c]	15.6±1.14[d]
1280	30	42.7±2.54[c]	2.1±0.11	45.4±2.70[c]	16.1±0.68[d]

*Ns = number of secondary follicles; Np = number of primary follicles; N(p+s) = total follicle population; S/P ratio = secondary to primary follicle ratio.

[a,b,c,d]Means in the same column with different superscripts differ ($P < 0.05$).

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Early Summer vs. Late Summer Diets of Sheep Grazing in a Conifer Plantation[1]

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Summary

Prescribed sheep grazing is an effective tool for controlling competing vegetation and enhancing growth of young conifer trees. Sheep producers would be more willing to graze their sheep according to silvicultural prescriptions if producers could better predict the nutritive quality of sheep diets. Foresters would be more inclined to use this silvicultural tool if they could better predict which plants sheep will eat. This study tested three hypotheses: (1) diet selection by sheep favors forbs in early summer and shrubs in late summer; (2) conifers comprise a very small proportion of sheep diets in either season of grazing; and (3) the nutritive quality of sheep diets is greater in early summer but adequate for gain in both early summer and late summer. Ewe-lamb pairs were grazed within a conifer plantation in northern Idaho for three summers. Botanical composition of sheep diets was estimated using microhistological analysis of fecal samples. Diet selection by sheep strongly favored grasses and sedges (i.e., graminoids) vs. forbs or shrubs, regardless of grazing season. Overall, sheep diets averaged 58% graminoids. Sheep generally selected forbs more in late summer than in early summer. Sheep consumed shrubs more in late summer during a dry, hot year, but during a wet, cool year sheep ate more shrubs in early summer than in late summer. Sheep consumption of conifers was not affected by grazing season, and conifers averaged 4% of sheep diets. Nutritive quality of sheep diets was evaluated based on levels of nitrogen (N) and diaminopimelic acid (DAPA) in sheep feces. Higher levels of fecal N and fecal DAPA generally correspond to greater nutritive quality in sheep diets. Both fecal N and fecal DAPA tended to be greater in early summer vs. late summer. Predictive equations based on these indices suggested that sheep performance suffered during the late summer grazing period.

Key Words: prescribed grazing, fecal nitrogen, diaminopimelic acid, nutrition, forage selection

Introduction

Prescribed grazing by domestic sheep is an effective tool for controlling competing vegetation and enhancing the growth of young conifer trees (Sharrow, 1994). This tool has been used successfully in the Pacific Northwest of the United States and Canada (Newsome and Sutherland, 1989; Sharrow et al., 1992), the American Southwest (Pearson, 1923), and the southeastern United States (Barnes, 1984). Prescribed sheep grazing has also enhanced tree growth in New Zealand (Beveridge and Klomp, 1973) and in Australia (McKinnell, 1975).

Despite these and numerous other successful examples, prescribed sheep grazing for conifer enhancement has not been applied to many sites where this tool is well-suited. One reason is that foresters often fear that sheep will eat the conifers and thereby cause more harm than good. But conifers are seldom selected by sheep when other green forage is available (Leininger and Sharrow, 1987). Douglas-fir comprised only 0.9-1.6% of summer sheep diets in western Oregon (Leininger and Sharrow, 1987). McCoy (1995) in northern Idaho reported that in one summer only 4.6% of sheep diets was conifers, while in another year conifers comprised less than 1% of sheep diets. But when graminoids and shrubs are unpalatable or unavailable, sheep may readily consume conifers (McKinnell, 1975). Hall et al. (1959) reported that 80% of the young conifer trees present in their study were browsed by sheep when sheep entered a conifer plantation too

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early, before the other forages in the plantation were sufficiently developed and plentiful. Leininger and Sharrow (1987) reported that 60-70% of terminal leaders were browsed on young trees in May compared to only 1% in July. In northern Idaho, MacRae (1996) similarly found more terminal leader browsing by sheep in June than in August, although browsing of lateral branches was greater in August. More information is needed about the effects of different grazing seasons upon the botanical composition of sheep diets when grazing in conifer plantations.

Another limitation to using prescribed sheep grazing to enhance conifer growth is that considerable uncertainty exists about the nutritive quality of sheep diets and sheep performance (i.e., weight gain) when sheep are managed according to grazing prescriptions that emphasize enhanced tree growth rather than livestock production. Few producers are willing to contribute their sheep gratis for this purpose if sheep performance suffers. McCoy (1995) found that sheep weight gain in a conifer plantation depended heavily upon precipitation and temperatures during the growing season. Average daily gain (ADG) of yearling Targhee ewes in summer ranged from 105 to 164 g when precipitation and temperatures approximated the long-term average for the study site, but ADG ranged from -14 to 45 g during an unusually hot and dry year. Hall et al. (1959) documented ADG in western Oregon conifer plantations exceeded 220 g during the spring green feed period in April through June. Similarly, Leininger et al. (1989) reported that yearling ewes accrued 88% of their total summer weight gain during May and June when the forage in conifer plantations was most palatable and nutritious.

In this study we compared the effects of early summer vs. late summer grazing on the nutritive quality and botanical composition of sheep diets within a northern Idaho conifer plantation. We tested three hypotheses: (1) sheep diet selection favors forbs in early summer and shrubs in late summer; (2) conifers comprise a very small proportion of sheep diets in either season; and (3) nutritive quality of sheep diets is greater in early summer but adequate for gain in both grazing seasons.

Materials and Methods

Study Area

The study site was located in north-central Idaho on the Flat Creek Unit of the University of Idaho Experimental Forest, about 70 km northeast of Moscow, Idaho. Climate of the area is temperate with cool, moist winters and warm, dry summers. The site has a predominant east to northeast aspect at an elevation of 1050-1100 m. Slopes range from 25-40%, and the soil is an ashy, mixed, frigid Vitric Hapludand (Barker, 1981). Annual precipitation averages 650 mm, with about 30% received as rainfall from May to September (NOAA, 1995).

The site was a western redcedar/queencup beadlily (*Thuja plicata/Clintonia uniflora*) habitat type (Cooper et al., 1991). It had been clear-cut in fall-winter 1985-1986 and replanted with ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), western white pine (*Pinus monticola*) and western larch (*Larix occidentalis*) in Spring 1987. Natural tree regeneration was dominated by Douglas-fir, western redcedar, and grand fir (*Abies grandis*). The understory vegetation consisted primarily of shrubs. Predominant shrub species were redstem ceanothus (*Ceanothus sanguineus*), common snowberry (*Symphoricarpos albus*), ninebark (*Physocarpus malvaceus*), rose (*Rosa* spp.), western thimbleberry (*Rubus parviflorus*), and Scouler willow (*Salix scouleriana*). Major forbs present were thistle (*Cirsium* spp.), bracken fern (*Pteridium aquillinum*), fireweed (*Epilobium angustifolium*), and mullein (*Verbascum thapsus*). The most common graminoids on the site were sheep fescue (*Festuca ovina*), bluegrass (*Poa* spp.), and elk sedge (*Carex geyeri*).

The grazing treatments were applied within a 4.5-ha enclosure delineated with a predator-proof electric fence. The site was divided into three blocks, each of which was subdivided into two 0.25-ha treatment pastures. The treatments were blocked to account for effects from previous grazing experiments on the study site (McCoy, 1995; MacRae, 1996). Each pasture within each of the three blocks was randomly assigned either an early summer or late summer grazing treatment. An adjacent 1.5-ha holding pasture was used to acclimate sheep to the forage on the study site before the sheep entered the treatment pastures.

Vegetation Sampling and Analyses

Vegetation was sampled in each pasture immediately before and after sheep grazing. Ten 50 x 50-cm quadrats were placed at 10-m intervals along a transect randomly located near the middle of each pasture. The current annual growth of grasses, forbs, and shrubs was then separated by life form and clipped from 2.5 cm above ground level within the quadrats. Current annual growth above 1.1 m was considered unavailable to the sheep (Patton and Hall, 1966). All clippings were placed in paper bags, oven-dried at 90^E C for 48 hr, and weighed. In 1995 before the quadrats were clipped, the dry-weight-rank method (t'Mannetje and Haydock, 1963) was used to estimate the botanical composition of each pasture. We used 70, 21, and 9 as multipliers in the dry-weight-rank method (t'Mannetje and Haydock ,1963).

Percent relative forage utilization was based on the amount of total forage available immediately before and after the grazing periods. Relative utilization measures how much of the current year's vegetative growth has been removed relative to how much has grown thus far in the growing season (Frost et al., 1994).

The duration of each grazing period was calculated by dividing the amount of total usable forage in a pasture by the daily forage allowance for the sheep, and averaging the results from the three pastures. Total usable forage was considered to be 50% of the total forage available as estimated from the clipped quadrats. Based upon the forage disapperance ratio of 11.8 kg/day/455 kg cow (SRM, 1989), daily forage allowance was considered to be 2.6 kg DM per 100 kg liveweight of sheep. Body weight of ewes averaged 95 kg, and their spring-born lambs averaged 30 kg. In 1993 and 1994, 24 Targhee ewes and their lambs (16 lambs in 1993, 35 lambs in 1994) were divided equally among the three treatment pastures in early summer and again in late summer. The same 24 Targhee ewes were used in 1993 and 1994. In 1995, 24 Panama ewes and their 39 lambs were similarly allotted to the three treatment pastures during the early-summer grazing season. The same 24 Panama ewes grazed in late summer 1995 without their lambs because the lambs had already been weaned. Early summer grazing treatments were in early June and lasted 11, 8, and 6 days in 1993, 1994, and 1995, respectively. Late summer grazing treatments were in early August and lasted 9, 7, and 10 days in 1993, 1994, and 1995, respectively.

Fecal Sampling and Analyses

Sheep diet selection and diet nutritive quality were estimated from fecal samples. Sheep fecal samples were collected from the ground in early morning 48 hr after grazing periods began and again 48 hr after grazing periods ended to account for rate of passage. Fresh pellets were collected from each of the eight ewes in a treatment pasture. Pellets were placed in sealable plastic bags, placed on ice in a cooler, and promptly transferred to a freezer. The two fecal samples per grazing period were later composited, resulting in a total for the study of 18 fecal samples (3 treatment pastures x 2 grazing seasons x 3 years) for laboratory analyses.

Botanical composition of the sheep diets was estimated from microhistological analysis of the sheep feces (Sparks and Malechek, 1968). In 1995 only, sheep diet selection was further evaluated with relative preference indices (RPI). Relative preference for each of the forage classes (i.e., grasses, sedges, total graminoids, forbs, and shrubs) was calculated by dividing the percent of each forage class in the diet (i.e., in the feces) by its percent composition in the pasture (Krueger, 1972). Values of RPI greater than 1 suggested preference, values less than 1 indicated avoidance, and values equal to 1 indicated that the forage class was neither preferred or avoided.

Diet nutritive quality was evaluated by analyzing the feces for total nitrogen (AOAC, 1990) and 2,6-diaminopimelic acid (DAPA) (Davitt and Nelson, 1984). Microhistological, fecal N, and fecal DAPA analyses were performed by experienced technicians at the Washington State University Habitat Laboratory.

Experimental Design and Statistical Analyses

The experimental design was a randomized block with two grazing treatments (early summer vs. late summer). Each treatment had three replicates (i.e., three pastures). Temporal variation was included in the study by applying the treatments for three years (1993, 1994, and 1995). Repeated measures analysis of variance was used to compare the effects of grazing season on the diet selection by sheep and the nutritive quality of sheep diets. Each forage class and nutritive variable were analyzed separately. Least Squares Means (SAS Institute, 1990) were used to compare treatment means. Significant differences were declared at $p \leq 0.10$. When treatment x year interactions occurred, each year's data were analyzed separately. RPI was evaluated with confidence intervals as recommended by Hobbs and Bowden (1982).

Results and Discussion

Relative forage utilization was moderate, averaging 47% in early summer and 42% in late summer. Actual utilization levels of 46-53% are considered moderate for forested sites in the Pacific Northwest (Kingery and Graham, 1991).

Diet Selection by Sheep

Sheep diets in early summer vs. late summer did not differ ($P > 0.10$) in the amount of grasses (x = 42%), sedges (x = 16%), total graminoids (x = 58%), or conifers (x = 4%) (Table 1). Across the two different grazing seasons and three different years of the study, total graminoids comprised from 50-74% of sheep diets whereas conifers comprised from 0-9%. It is noteworthy that sheep consumption of conifers was lowest in 1994 when environmental conditions were hotter and drier than normal (NOAA, 1994). As long as alternative forage is sufficiently plentiful, sheep are less likely to consume conifers when the twigs and needles of the trees are dry and coarse (Pearson, 1950; Leininger and Sharrow, 1989).

Forb content in the diets had a grazing season x year interaction ($P \leq 0.10$). Forb content did not differ between early summer and late summer in 1993, but forb content was greater in late summer in both 1994 and 1995. Shrub content in sheep diets also had a grazing season x year interaction ($P \leq 0.10$). In 1994, shrub content was greater ($P \leq 0.10$) in late summer, but in 1995 shrub content was greater ($P \leq 0.10$) in early summer. We attribute these interactions to differences in environmental conditions among years. Environmental conditions in 1994 were slightly hotter and drier than the 29-year average (NOAA, 1994). In 1994, sheep selected less graminoids and more forbs and shrubs in late summer than they had in early summer. The graminoids matured quickly and the remaining forbs and shrubs became relatively more palatable. In 1995, sheep also selected more forbs in late summer compared with early summer, while concomitantly decreasing shrub consumption in late summer. Environmental conditions in 1995 were cooler and wetter than the 29-year average (NOAA, 1995). This enabled graminoids and forbs to remain more palatable later into the growing season.

Preference indices suggested that sheep strongly preferred graminoids and disfavored shrubs, regardless of grazing season (Table 2). Forbs were slightly disfavored overall and in early summer, although forb selection by sheep was neutral in late summer (Table 2).

Nutritive Quality of Sheep Diets

Two fecal indices, fecal N and fecal DAPA, were used to compare sheep diet quality in early summer vs. late summer. Fecal N had a grazing season x year interaction ($P \leq 0.10$). Fecal N was lower in late summer of 1993 and 1994, but fecal N did not differ between grazing seasons in the wetter, cooler year of 1995 (Table 3). Lower fecal N values generally indicate lower diet nutritive quality (Van Soest, 1994).

Dietary N can be estimated from fecal N using regression equations. Kothmann and Hinnant (1987) developed an equation for sheep and goats. Using this equation [$DN = 1.33(FN) - 0.73$], fecal N values in our study indicated that dietary N averaged no less than 2.2% in any grazing season x year combination. This equated to a minimum crude protein (CP) content in the sheep diets of about 14% [$CP = N \times 6.25$]. The NRC (1985) suggests that 50-70-kg replacement ewe lambs require a diet that is 9.1% CP, whereas 70-90-kg lactating ewes require 13.4-13.1% CP. Hodgmann et al. (1996) developed a regression equation to relate fecal N to dietary CP. This equation was developed for deer (*Odocoileus* spp.) fed forages very similar to those consumed by sheep in our study. Using their equation [$CP = 28.81 - 29.55\ (1/FN)$], fecal N values in our study indicated that CP in the sheep diets averaged no less than 15% in any grazing season x year combination. This predicted value corresponds closely with the 14% dietary CP predicted by the equation from Kothmann and Hinnant (1987).

Hodgmann et al. (1996) also developed a regression equation to relate fecal N to digestible energy intake (DEI). This equation [$DEI = 7.94 + 8.62\ (FN)^2$] predicted that daily DEI by sheep in our study averaged 78.4 kcal/kg BW in early summer and 54.3 kcal/kg BW in late summer. Accordingly, 50-70-kg replacement ewe lambs would have consumed about 3.9-5.5 Mcal DE/day in early summer and 2.7-3.8 Mcal DE/day in late summer. The NRC (1985) suggests that 50-70-kg replacement ewe lambs require 3.9 Mcal DE/day. It appears that the DE level was adequate for replacement lambs in early summer but not during the late summer grazing season, especially for lambs weighing less than 70 kg. This result corresponds well to a recommendation by Leininger et al. (1989) that lambs not graze in Pacific Northwest conifer plantations after mid-summer because the browse is too indigestible and inhibits sheep from meeting their nutritional requirements. Furthermore, the equation of Hodgmann et al. (1996) predicted that a 70-90-kg ewe would have consumed about 5.5-7.0 Mcal DE/day in early summer and 3.8-4.9 Mcal DE/day in late summer. These levels of DE are below the 7.2-7.6 Mcal DE/day suggested by NRC (1985) for 70-90-kg ewes in late lactation. However, the predicted DEI in both early and late summer was adequate for non-lactating mature ewes (NRC, 1985).

Fecal DAPA was greater ($P \leq 0.10$) in early summer (0.8 mg/g DM) vs. late summer (0.6 mg/g DM) (Table 3). Greater fecal DAPA values generally indicate higher diet nutritive quality (Kie and Burton, 1984; Leslie et al., 1989; Hodgmann et al., 1996). Fecal DAPA values in both early and late summer were less than those reported for black-tailed deer (*Odocoileus hemionus columbianus*) and mule deer (*O. h. hemionus*) in northern California forests (Kie and Burton, 1984) and for white-tailed deer (*Odocoileus virginianus*) in Maine (Leslie et al., 1989). But fecal DAPA values in our study were similar to those of black-tailed deer and mule deer in northern Idaho and eastern Washington (Hodgmann et al., 1996), and similar to those of domestic sheep in north-central Idaho evaluated by McCoy (1995), whose study preceded ours on the same site.

Hodgmann et al. (1996) developed separate regression equations to relate fecal DAPA to dietary CP and to DEI. These equations were developed from deer fed forages very similar to those consumed by sheep in our study. Using their predictive equation for dietary CP [$CP = \exp(3.5 - 0.68\ (1/DAPA)$], our fecal DAPA values estimated that dietary CP was 13.4% in early summer vs. 9.8% in late summer. These values are greater than the 9.1% CP requirement suggested by NRC (1985) for 50-70-kg replacement ewe lambs. The 13.4-13.1% CP requirement suggested by NRC (1985) for 70-90-kg lactating ewes was met in early summer but not in late summer.

Our fecal DAPA values inserted into the Hodgmann et al. (1996) predictive equation for DEI [$DEI = \exp(4.153 + 1.353\ (\ln DAPA))$] estimated that daily DEI for our sheep was 43.1 kcal/kg BW in early summer and 29.0 kcal/kg BW in late summer. These values suggest that a 50-70-kg replacement ewe lamb would have consumed about 2.2-3.0 Mcal DE/day in early summer and 1.4-2.0 Mcal DE/day in late summer. These values are all well below the daily requirement of 3.9 Mcal DE suggested by NRC (1985) for replacement ewe lambs of this size. The predictive equations suggest that a 70-90-kg lactating ewe in our study would have consumed about 3.0-3.9 Mcal DE/day in early summer, and 2.0-2.6 Mcal DE/day in late summer. These values are well below the daily requirement of 7.4-7.6 Mcal DE/day suggested by NRC (1985) for 70-90-kg lactating ewes. In contrast, the maintenance requirement of a 70-90-kg ewe is only 2.9-3.4 Mcal DE/day (NRC, 1985).

Conclusions

Graminoids, forbs, and shrubs often compete with young conifer trees for water, nutrients, and light (Stewart et al., 1984). The relative amount of competition from each forage class is site-specific, and grazing prescriptions should be locally-tailored to control plants that are most limiting to tree growth. Results from this study indicate that when grazing in Pacific Northwest conifer plantations, sheep prefer to eat graminoids in both early summer and late summer. Sheep will likely eat increased amounts of forbs and shrubs in late summer if environmental conditions cause graminoids to become disproportionately more dry and coarse than other forages. Sheep will likely select more forbs in late summer during cool, wet years in which forbs remain more palatable later into the growing season. Thus, for those sites where forbs significantly compete with conifers, prescribed sheep grazing is best-applied during cool, wet years. Sheep browsing of conifers will be minimal throughout the summer if alternative forages are palatable and plentiful, especially during dry, hot years in which conifer twigs and needles are less moist or pliable. Therefore, where sheep browsing of conifers is anticipated to be abnormally high, these sites are best grazed by sheep during dry years..

The nutritive quality of sheep diets and sheep performance may suffer when conifer plantations in the Pacific Northwest are grazed in late summer. Dietary CP generally appears adequate throughout the summer, but DEI in late summer may be inadequate for lambs to gain sufficiently. This is especially true for lambs that weigh less than 70 kg. Lactating ewes will likely lose body condition in late summer. Therefore, older and/or larger lambs, or dry ewes, or mature wethers are better suited to grazing conifer plantations in late summer. Sheep producers sometimes may need to receive some form of compensation for reduced sheep performance when silvicultural prescriptions require sheep to graze plantations in late summer. It is important to remember, however, to evaluate the nutritional status of sheep within the proper context. The nutritional status of sheep does not always need to meet NRC requirements if the sheep are in good body condition (Kott, 1998), especially for ewes after lactation and a few weeks before breeding (i.e., late summer). Ewes in good body condition can readily compensate by consuming high quality diets immediately prior to breeding. Older wethers, and replacement ewe lambs that will not be bred until they are yearlings, also may be able to sacrifice body condition in late summer. Conversely, rams and replacement ewe lambs that will be bred as lambs cannot afford to lose body condition in late summer.

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Table 1. Mean (± SE) botanical composition of sheep diets in early summer (ES) vs. late summer (LS).

Forage Class	1993 ES	1993 LS	1994 ES	1994 LS	1995 ES	1995 LS	Mean ES	Mean LS
				%				
Grasses	38.7 ± 2.5a[†]	48.2 ± 3.3a	51.4 ± 3.7a	32.8 ± 2.4b	44.1 ± 2.4a	37.5 ± 3.7a	44.7 ± 3.7a	39.5 ± 4.6a
Sedges	14.6 ± 1.4a	10.4 ± 3.0a	23.0 ± 3.2a	20.0 ± 1.4a	14.7 ± 3.9a	12.2 ± 1.5a	17.4 ± 2.8a	14.2 ± 2.9a
Total Graminoids	53.3 ± 3.5a	58.6 ± 1.0a	74.4 ± 0.9a	52.7 ± 2.5a	58.9 ± 6.3a	49.8 ± 5.1a	62.2 ± 6.3a	53.7 ± 2.6a
Forbs	28.7 ± 3.5a	27.9 ± 3.0a	21.8 ± 1.1a	34.6 ± 1.2b	16.8 ± 3.4a	30.5 ± 1.8b	22.4 ± 3.4	31.0 ± 0.6
Shrubs	16.0 ± 1.0a	10.1 ± 1.7a	3.5 ± 1.0a	11.1 ± 1.3b	15.7 ± 0.7a	11.5 ± 0.6b	11.7 ± 4.1	10.9 ± 0.4
Conifers	3.8 ± 3.7a	3.4 ± 1.3a	0.4 ± 0.3a	1.4 ± 1.0a	8.6 ± 2.5a	7.9 ± 3.1a	4.3 ± 2.4a	4.2 ± 1.9a
Total	100	100	100	100	100	100	100	100

[†]Values within the same row and year with the same letter are not different ($P > 0.10$).

Table 3. Mean (± SE) nitrogen and diaminopimelic acid (DAPA) levels in sheep feces in early summer (ES) vs. late summer (LS).

Fecal Index	1993 ES	1993 LS	1994 ES	1994 LS	1995 ES	1995 LS	Mean ES	Mean LS
Nitrogen (%)	3.2 ± 0.05a[†]	2.3 ± 0.03b	2.9 ± 0.1a	2.2 ± 0.01b	2.5 ± 0.1a	2.4 ± 0.1a	2.9 ± 0.2	2.3 ± 0.1
DAPA (mg/g DM)	0.7 ± 0.02a	0.5 ± 0.0b	0.7 ± 0.04a	0.5 ± 0.02b	0.9 ± 0.04a	0.7 ± 0.02b	0.8 ± 0.07a	0.6 ± 0.07b

[†]Values within the same row and year with the same letter are not different ($P > 0.10$).

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Table 2. Relative preference indices (RPI) and confidence intervals (CI) for graminoids, forbs, and shrubs in early summer and late summer in 1995.

Grazing Season	Forage Class	RPI	90% CI
Early Summer	Graminoids	12.0	3.50 -- 20.50†
	Forbs	0.5	0.24 -- 0.76
	Shrubs	0.3	0.26 -- 0.34
Late Summer	Graminoids	7.4	4.90 -- 9.90
	Forbs	0.9	0.60 -- 1.20
	Shrubs	0.2	0.15 -- 0.25

†Confidence intervals calculated per Hobbs and Bowden (1982). When confidence intervals do not include 1.0, RPI > 1.0 indicates preference, whereas RPI < 1.0 indicates avoidance.

The Effects of Nutritional Management on Ewe and Lamb Bodyweight and Ewe Body Composition

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Summary

Mature Targhee ewes (N = 140) were used to evaluate the effects of nutritional management on ewe body weight, body composition, and lamb production. Nutritional management systems were: 1) year around grazing, LOW; 2) 11 months of grazing and drylot fed in Feb, FEB; 3) 11 months of grazing and drylot fed in Mar, MAR; 4) seven months of grazing and five months of drylot feeding, INTENSIVE. Immediately before breeding, 30 days before lambing, and at weaning, ewes were weighed and body composition estimated using the urea dilution technique. Lamb weights were recorded at 45, 90, and 135 (weaning) days of age. Nutritional management x number of lambs weaned interactions were detected (P < .10) for ewe and lamb body weight and ewe body composition. With the exception of kg of lean body tissue during late gestation, INTENSIVE ewes weaning single or twin lambs had greater (P < .10) body weight and kg of lean body tissue than LOW, FEB, and MAR ewes during gestation and at weaning. INTENSIVE ewes weaning single lambs had greater (P < .10) kg of body fat than FEB, or LOW and FEB ewes during gestation and weaning, respectively. However, percent body fat did not differ among nutritional management treatments for ewes weaning single lambs. INTENSIVE ewes weaning twin lambs had greater (P < .10) kg and percent body fat than LOW, FEB, and MAR ewes during late gestation. Although INTENSIVE ewes weaning twin lambs had greater (P < .10) kg of body fat at weaning, management treatments did not differ in percent body fat at weaning for ewes weaning twins. Kilograms of lamb weaned per ewe did not differ among nutritional management treatments for ewes weaning single lambs. Kilograms of lamb weaned per ewe did not differ between INTENSIVE and LOW ewes weaning twin lambs. However, both the INTENSIVE and LOW ewes weaning twins had greater (P < .10) kg of lamb weaned per ewe than MAR ewes weaning twin lambs. These results indicate that nutritional management systems effect both lean and fat components of body composition and how these components change over time.

Introduction

Sheep management systems should have the ultimate goal of producing quality lamb and wool at the lowest unit cost of production possible for a given environment. Feed represents the largest single production cost in all types of sheep operations (SID, 1992). The level of harvested feed inputs may be the primary component influencing ewe body composition and ewe and lamb body weight. Although there is a wealth of information on the influence of different types and levels of nutrients on ruminant body weight and, to a lesser extent, body composition, there is little information on the influence of nutritional management systems on body weight and composition.

In this study, we evaluated body weight and composition in ewes and lambs (body weight only) managed under four different nutritional management systems. The LOW system represented a year-around grazing system. The FEB system incorporated confinement feeding of harvested feeds during the month of February (typically the most critical part of the winter) with 11 months of grazing. The MAR system incorporated confinement feeding of harvested feeds during the month of March (mid to late gestation) with 11 months of grazing. The INTENSIVE system follows a more traditional management style in which harvested feeds are used five months each year. Our objective was to compare changes in ewe and lamb body weight and ewe body composition as influenced

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by the different nutritional management systems.

Material and Methods

Targhee ewes (N = 140; 2 to 6 years of age, avg. age = 3.5) were used to study the influence of nutritional management systems on changes in ewe body weight, ewe body composition, and lamb production. Thirty-five ewes were randomly selected from each of four different management systems having a minimum of 120 ewes/system. The following is a description of the four nutritional management systems (Figure 1).

LOW Starting in October ewes grazed alfalfa aftermath, volunteer grains, and winter wheat until December. From December until March ewes grazed barley stubble. During December and January ewes were pastured mated. While grazing barley stubble, ewes were supplemented daily with .23 kg of a 25% CP pellet consisting of urea and wheat middlings. Supplement was fed on the ground. Ewes were fed alfalfa hay (18% CP) when dictated by snow depth. Starting in early March ewes grazed a native sagebrnsh-bunchgrass range in southern Idaho. In early April ewes were moved to the U. S. Sheep Experiment Station near Dubois, ID, where they were range lambed in May and June. Ewes and lambs grazed intermountain sagebrush-bunchgrass until weaning in early October.

FEB Ewes followed the same system as previously mentioned except during February, ewes were placed in drylot for 30 days and allowed ad libitum access to alfalfa hay (18% CP) and given .23 kg of whole barley per ewe daily. After confinement, they returned to grazing. In this system, ewes were confined and fed harvested feeds during the portion of winter that typically has the poorest forage availability (because of snow cover) and the coldest temperatures.

MAR Ewes were managed in the same manner as the LOW group, but confined for 30 days in late March/early April, allowed ad libitum access to alfalfa hay (18% CP) and given .23 kg of whole barley per ewe daily. After confinement ewes returned to grazing. In this system, ewes were confined and fed harvested feeds during a physiological period of high-energy demand (mid to late gestation).

INTENSIVE Starting in September, ewes grazed intermountain sagebrush-bunch grass range until the end of October. In early November, ewes were placed in single sire breeding pens, and allowed ad libitum access to alfalfa hay (18% CP) and fed .23 kg of barley until late December. From late December until early February, ewes grazed native range. From February until late April ewes were placed in drylot and allowed ad libitum access to alfalfa hay (18% CP). In March and April, each ewe was also fed .45 kg of whole barley daily. Ewes were shed lambed starting in late March. From late April until late June, ewes grazed intermountain sagebrush-bunch grass range. Ewes grazed alpine meadow range from July until weaning in September.

Two years prior to this study all ewes had been in the INTENSIVE management system. In the year prior to this study, ewes in the LOW, FEB, and MAR nutritional management groups had been managed as one group. At this time, all ewes in the LOW, FEB, and MAR systems had been managed as described for the LOW nutritional management system.

Hatfield (1995) described nutrient content of the spring, summer, and fall grazing locations. For all nutritional management groups, forage quantity was typically not limiting on winter ranges except for the few days ewes on the LOW, FEB, and MAR were fed hay because of snow cover.

Data Collection

All ewes were weighed (after 18 hours without feed or water) and body composition estimated using the urea dilution technique (Preston and Kock, 1973) immediately before breeding (pre-breeding), at 120 days of gestation (late gestation), and at weaning. Lambs were weighed at 45, 90, and 135 days of age. Because the LOW, FEB, and MAR groups started lambing in mid May and the INTENSIVE group started lambing at the end of March, sampling dates were not the same for all ewes. Sampling dates corresponded to ewe physiological stage rather than calendar date. Thus, ewes in the LOW, FEB, and MAR treatments were

Table 1. Pre-breeding ewe body weight and body composition for all ewes

	LOW[a]	FEB[b]	MAR[c]	INTENSIVE[d]	SEM
Body weight, kg	72.2	71.9	73.9	72.8	1.65
Lean, kg	52.6	52.4	55.1	53.4	1.36
Fat, kg	19.1	19.4	19.8	19.2	.76
Fat, %	26.4	27.1	26.4	26.4	.81

[a] LOW, year around grazing
[b] FEB, 11 months grazing with drylot feeding in February
[c] MAR, 11 month grazing with drylot feeding in March
[d] INTENSIVE, 8 months grazing with drylot feeding from November to December and February to April

sampled on the same calendar date, but INTENSIVE ewes were sampled approximately 30 days earlier.

The day before urea dosing, the necks of ewes were shorn and a 20% urea solution in normal saline was prepared. On the day of urea dosing, a baseline blood sample (T_0) was collected in a 10-mL vacutainer (non-heparinized) via jugular venipuncture. Following the T_0 sample, ewes were infused with 0.66 to 0.75-mL urea solution for each kg of body weight via a 19 ga winged jugular catheter. Twelve minutes after infusion, a second blood sample (T_{12}) was collected via jugular venipuncture in a 10 mL non-heparinized vacutainer. Blood samples were centrifuged at 3000 x g for 10 minutes. Sera and an aliquot of the urea solution dose were transferred to polypropylene storage tubes, capped, and frozen for later analysis. When samples were ready to be analyzed, they were removed from the freezer and thawed in a refrigerator. Urea concentration was determined by spotting 10 uL of sample on a Kodak[1] blood urea nitrogen slide. Slides were read on a Kodak DT-60. Percent lean and fat were calculated in the following manner (Preston and Kock, 1973).

$$\frac{(\text{Dose Amount} \times \text{Dose Concentration})}{(T_{12}BUN - T_0BUN) \times \text{Time Correction Factor}} \times 1000 = \%\ \text{Urea Space}$$

$$\%\text{Lean} = \%\ \text{Urea Space}/.0075$$

$$\%\ \text{Fat} = 100 - \%\ \text{Lean}$$

Body, lean, and fat weights, and % body fat changes from pre-breeding (PB) to late gestation (LG) were calculated as [(PB – LG)/ PB] x 100. Values for changes from late gestation to weaning (W) were calculated as [(LG - W)/ LG] x 100. Percent

Table 2. Body weight and composition during late gestation and at weaning for ewes that weaned a single lamb

Item	LOW[a]	FEB[b]	MAR[c]	INTENSIVE[d]	SEM
Late Gestation					
Body weigbt, kg	68.0[e]	67.4[e]	72.7[e]	79.2[f]	3.08
Lean, kg	54.2[e]	54.2[e]	56.9[e]	62.2[f]	2.27
Fat, kg	13.8[ef]	13.2[e]	15.9[ef]	17.0[f]	1.77
Fat, %	20.3	19.7	21.6	21.2	1.75
Weaning					
Body weight, kg	65.2[ef]	61.9[e]	68.4[f]	79.2[g]	2.92
Lean, kg	48.1[ef]	44.9[e]	50.0[f]	58.6[g]	2.25
Fat, kg	17.1[e]	17.0[e]	19.4[ef]	20.0[f]	1.35
Fat, %	26.1	27.6	27.9	25.4	1.54
Percent change					
Pre-breeding (PB) to late gestation (LG)[i]					
Body weight, kg	3.7[e]	2.9[e]	-2.7[f]	13.8[g]	2.14
Lean, kg	13.1[e]	14.0[e]	4.1[f]	23.1[g]	3.71
Fat, kg	-17.1	-23.9	-18.6	-5.0	12.69
Fat, %	-20.8	-25.4	-17.4	-17.5	10.72
Percent change					
Late gestation (LG) to weaning (W)[j]					
Body weight, kg	-2.7[ef]	-8.9[e]	-3.5[ef]	1.0[f]	3.28
Lean, kg	-9.0[eg]	-17.6[f]	-12.6[ef]	-3.5[g]	3.47
Fat, kg	32.9	32.6	40.0	35.8	15.58
Fat, %	37.8	45.3	44.9	33.4	15.10

[a] LOW, year around grazing
[b] FEB, 11 months grazing with drylot feeding in February
[c] MAR, 11 month grazing with drylot feeding in March
[d] INTENSIVE, 8 months grazing with drylot feeding from November to December and February to April
[efgh] means within a row lacking a common superscript differ (P < .10)
[i] [(PB – LG)/ PB] x 100
[j] [(LG - W)/ LG] x 100

change in ewe body weight and composition were analyzed using the SAS (1988) general linear models analysis. The model included nutritional management, ewe age, number of lambs reared, and all two-way interactions. Ewe body weight, ewe body composition, and lamb body weight were analyzed using the SAS (1988) repeated measures analysis. The model included time, nutritional management, ewe age, number of lambs reared, and all two-way interactions and the three-way interaction of time x nutritional management x number of lambs reared.

Rook (1997) reported that 50% of lamb mortality occurs in the first three days of life, independent of the production scheme. Therefore, to evaluate nutritional management (independent of lambing system) on lamb body weight, lambs lost after three days of age (predation, illness, etc.) were not included in lamb body weight analysis.

Results

Interactions were detected (P < .10) for ewe and lamb body weight and ewe body composition for nutritional management x number of lambs reared, time x nutritional management, and time x number of lambs reared. Therefore, results are presented as the simple effects of number of lambs reared within time and nutritional management treatment.

Before LOW, FEB, and MAR were separated into their respective treatment groups, no differences in ewe body weight or kg of lean body tissue were detected among nutritional management groups (Table 1). Fetal number, determined by real-time ultrasound 45 days

Table 3. Body weight and composition during late gestation and at weaning for ewes that weaned twin lambs

Item	LOW[a]	FEB[b]	MAR[c]	INTENSIVE[d]	SEM
Late gestation					
Body weight, kg	80.4[e]	81.2[e]	72.1[f]	88.9[g]	2.44
Lean, kg	1.9[e]	63.0[eg]	55.8[f]	65.9[g]	1.86
Fat, kg	18.1[e]	18.8[e]	15.8[e]	22.8[f]	1.45
Fat, %	22.4[e]	22.8[e]	21.7[e]	25.5[f]	1.27
Weaning					
Body weight, kg	66.6[e]	67.0[e]	62.0[f]	77.7[g]	2.26
Lean, kg	49.0[e]	49.7[e]	45.2[f]	55.7[g]	1.94
Fat, kg	16.6[e]	17.7[e]	16.3[e]	21.2[f]	1.17
Fat, %	25.4	26.0	26.5	27.4	1.34
Percent change					
Pre-breeding (PB) to late gestation (LG)[i]					
Body weight, kg	7.0[e]	7.6[e]	.2[f]	17.9[g]	1.65
Lean, kg	12.1[ef]	13.2[eg]	6.1[f]	18.4[g]	3.08
Fat, kg	-.4[e]	-.1[e]	-8.3[e]	22.1[f]	10.60
Fat, %	-8.0	-7.7	-9.9	3.3	8.92
Percent change					
Late gestation (LG) to weaning (W)[j]					
Body weight, kg	-17.0[e]	-17.2[e]	-12.3[f]	-12.2[f]	2.54
Lean, kg	-20.2[e]	-21.7[e]	-18.4[ef]	-14.6[f]	3.01
Fat, kg	1.5	11.5	24.4	.2	13.49
Fat, %	18.5[ef]	31.7[ef]	41.4[e]	14.5[f]	13.08

[a] LOW, year around grazing

[b] FEB, 11 months grazing with drylot feeding in February

[c] MAR, 11 month grazing with drylot feeding in March

[d] INTENSIVE, 8 months grazing with drylot feeding from November to December and February to April

[efg] means within a row lacking a common superscript differ (P < .10)

[i] [(PB – LG)/PB] x 100

[j] [(LG - W)/LG] x 100

after the end of the breeding season, did not differ among nutritional management treatments. The LOW, FEB, and MAR were pasture mated as one group with a resulting average fetal number of 1.59. Fetal number for the INTENSIVE group was 1.60.

Ewes carrying and rearing single lambs

During late gestation, INTENSIVE ewes had greater (P < .10) body weight and kg of lean body tissue than LOW, FEB, and MAR ewes (Table 2). INTENSIVE ewes had greater (P < .10) kg of body fat than FEB ewes. The LOW and MAR ewes were intermediate in kg of body fat and did not differ (P > .17) from either the FEB or INTENSIVE ewes. No differences (P > .37) in percent body fat were detected among nutritional management groups for ewes carrying single lambs during late gestation.

At weaning, INTENSIVE ewes had greater (P < .10) body weight and kg of lean body tissue than LOW, FEB, and MAR ewes. Ewes in the FEB nutritional management group had lower (P < .10) body weight and kg of lean tissue than MAR ewes with LOW ewes being intermediate in both body weight and kg of lean body tissue. INTENSIVE ewes did not differ (P = .72) from MAR ewes in kg of body fat. INTENSIVE ewes had greater (P < .10) kg of body fat than LOW and FEB ewe. No differences were detected among nutritional management groups in percent body fat (P > .15).

From pre-breeding to late gestation, ewes in the INTENSIVE nutritional management group gained the greatest (P < .10) percentage of body weight and lean body tissue while MAR ewes lost body weight and had the lowest (P < .10) percent lean body tissue gain of the four treatment groups (Table 2). No differences (P > .15) were detected among treatments in percentage change in either percent or kg of body fat.

From late gestation to weaning, INTENSIVE ewes gained body weight while FEB ewes lost the most body weight (P < .10). Ewes in the LOW and MAR nutritional management groups were intermediate to INTENSIVE and FEB ewes in percent change in body weight. INTENSIVE ewes lost less (P < .10) kg of lean body tissue than FEB and MAR ewes, with LOW ewes being intermediate in kg of lean tissue loss. No differences in either kg or percent body fat change were detected among treatments.

Ewes carrying and rearing twin lambs

INTENSIVE ewes carrying twins during late gestation had greater (P < .10) body weight, kg of lean tissue (except compared to ewes in the FEB treatment), kg of fat, and percent body fat than LOW, FEB, and MAR ewes (Table 3). Ewes in the MAR nutritional management group had lower (P < .10) body weight and kg of lean body tissue than ewes in all other nutritional management groups.

At weaning, INTENSIVE ewes had greater (p < .10) body weight, kg of lean and fat body tissue than LOW, FEB, and MAR ewes (Table 3). Ewes in the MAR nutritional management group had lower (P < .10) body weight and kg of lean body tissue than ewes in all other nutritional management groups.

From pre-breeding to late gestation, INTENSIVE ewes gained the greatest (P < .10) and MAR ewes the least percentage of body weights among the four treatment groups. Rank among treatments in percent change in kg of lean body tissue was the same as percent change in body weight. INTENSIVE ewes percentage gain in lean body tissue did not differ from that of FEB ewes but was greater than values for MAR and LOW ewes. Percent change in lean body tissue did not differ between ewes in the MAR and LOW nutritional management group.

Ewes in the INTENSIVE nutritional management group gained (P < .10) while LOW, FEB, and MAR ewes lost in percentage of body fat. No differences were detected in percent change in percent body fat. However, INTENSIVE ewes gained while all other ewes lost percent body fat from pre-breeding to late gestation.

From late gestation to weaning, ewes in the INTENSIVE and MAR nutritional groups lost less (P < .10) body weight than LOW and FEB ewes (Table 3). INTENSIVE ewes lost less (P < .10) kg of body lean tissue than LOW and FEB ewes with MAR ewes being intermediate in kg of lean tissue loss. Ewes in the MAR nutritional management group gained more (P < .10) body fat percent than INTENSIVE ewes with LOW and FEB ewes being intermediate in percent body fat gain.

Lamb Body weight

At 45 days postpartum, body weight of single lambs reared by ewes in the INTENSIVE group was less (P < .10) than body weight of single lambs reared by ewes in the LOW and FEB nutritional management systems (Figure 2). This could be due in part to weather and forage conditions. Because lambs in the INTENSIVE group were born earlier than lambs in the LOW, FEB, and MAR groups, they were held in confinement and exposed to more severe weather conditions than lambs from the LOW, FEB, and MAR groups. No differences (P > .37) among nutritional management groups were detected in single lamb body weight at 90 and 135 days postpartum.

At 45 days postpartum, body weight of twin lambs reared by ewes in the MAR group were less (P < .10) than body weight of lambs reared by ewes in the LOW and FEB nutritional management systems. At 90 and 135 days postpartum, body weight of twin lambs reared by ewes in the MAR group was less (P < .10) than lambs reared by ewes in the LOW, FEB, or INTENSIVE groups. At 135 days postpartum, body weight of twin lambs reared by the FEB group was less (P < .10) than lambs reared by the INTENSIVE group (Figure 3).

Discussion

Ferrell and Jenkins (1985) stated that variation in maintenance energy requirements are 70 to 75% of total annual energy requirements and appear to be greater than variation in requirements for growth, gestation, or lactation. Studies reviewed by these authors suggest that animals that have genetic potential for high production may be at a disadvantage compared to lower potential animals in nutritional restricted environments. Further, they stated that little of the variation in maintenance energy requirements is attributable to body composition. However, if management systems have the potential of affecting body composition as noted in this study, systems may ultimately influence energy maintenance requirements via differences between low (fat) and high (protein) metabolically active tissue.

In general, INTENSIVE ewes responded to the increased input of harvested feeds by having greater kg of body weight, lean tissue and fat during late gestation and at weaning than the other three nutritional management groups. Except for ewes carrying twin lambs during late gestation, percent body fat was consistent among treatments during late gestation and at weaning. Weight loss and body composition changes have been associated with low nutritional levels in sheep (Farrell and Reardon, 1972; Panaretto, 1964); However, it is not clear at what level low nutrition actually results in a loss of production that negatively impacts cost of lamb production.

For ewes with single lambs, the higher nutritional plane resulted in greater body weight composed of both fat and protein. However, it had no apparent positive influence on lamb body weight and for some unfound reason it had a negative impact on lamb weights at 45 days of age. Possibly the higher nutritional plane may have repartitioned nutrients away from milk and to body energy reserves. Only when comparing weaning weight of twins by INTENSIVE ewes to FEB and MAR ewes did high nutritional inputs result in more kg of lambs. However, the LOW nutritional management group did not differ from the INTENSIVE group. This may indicate some stress associated with confinement feeding hindered lamb body weight gain. The low body weights of twins reared in the MAR nutritional group compared to the LOW group may indicate higher feed inputs are not needed when weather conditions allow adequate grazing.

From pre-breeding to late gestation, all ewes gained body weight, with the exception of MAR ewes carrying a single fetus. All ewes increased kg of lean tissue during this period and lost kg of body fat, including MAR ewes carrying a single fetus. From late gestation to weaning, all ewes lost body weight, with the exception of INTENSIVE ewes rearing a single lamb. All ewes lost kg of lean tissue during this period and gained kg of body fat including INTENSIVE ewes rearing a single lamb. Brendemuhl et al. (1989) concluded that sows fed protein deficient diets lost large amounts of protein from muscle tissue and internal organs. Possibly, milk production in grazing ewes draws heavily on body protein. Why ewes gain body fat is not clear. However, having a lower proportion of body protein (high metabolic activity) compared to fat (low metabolic activity) may allow the ewe a lower cost of maintenance through the winter.

Taylor et al. (1996) reported that body condition score was linearly related to carcass crude protein (R^2= .73) and carcass lipid (R^2= .78), but explained less variation in organ crude protein (R^2= .34) and organ lipid (R^2= .24) concentration. Sanson et al. (1993) reported that in western-range ewes, condition score was highly related to carcass lipids and could be used to estimate body energy reserves. However, Sanson et al. (1993) used 14 ewes with an average condition score of 7.5 [scale ranged from 1, (emaciated) to 9, (obese)]. They had 7 ewes that were a condition score 8, the remaining were 1, 2, 1, and 3 ewes that were condition score 6, 3, 2, and 1, respectively. In essence, these researchers showed a linear relationship among extremes in body condition rather than an evenly distributed range in body condition.

Preston and Kock (1973) reported that the relation between urea space determined at 12 or 15 minutes after infusion in 12 steers was highly correlated (r = .96) with percentage empty body fat and percentage empty body water. Bartle and Preston (1986) concluded that in a 12 minute time-frame, the infused urea did not pass the rumen wall. Preston (personal communication) suggested that the same may hold true for the placental barrier with no urea passing the barrier during the 12 minute collection period. Thus, estimates of ewe body composition using urea dilution during gestation are not confounded with fetal tissue.

Brendemuhl et al. (1987) fed lactating primiparous sows four diets differing in concentrations of protein and energy. The diets were low energy and low protein, low energy and high protein, high energy and low protein, and high energy and high protein. As expected, the sows fed the low-low combination lost the most body weight and sows fed the high-high lost the least amount. However, sows fed the low energy diet lost less weight when fed high protein compared to sows fed low protein diets. Sows lost less body condition when fed the high energy diet compared to those fed the low energy diet. The opposite effect occurred, however, with the protein treatments. Sows that received the high protein diet lost more body condition suggesting a greater mobilization of adipose stores and a difference in the composition of weight loss dependant upon diet. However, Taylor et al. (1995) reported that only 42% of the variation in back fat thickness could be accounted for by body condition. This may indicate that in the study by Brendemuhl et al. (1987) that a loss of body condition is not solely a lose in body fat tissue. Other researchers have shown that body protein is a mobile source of energy or amino acid precursors. Taylor et al. (1995) reported that muscle appears to be a significant source of energy stores for ewes and is mobilized immediately during periods of restricted nutrition, similar to stores of fat.

Brendemuhl et al. (1989) concluded from a slaughter experiment, that sows fed protein deficient diets lost large amounts of protein from muscle tissue and internal organs while an energy deficient diet resulted in primarily loss of fat. In our study, diet quality was not estimated; however, a protein deficiency during late lactation is possible and may account for the loss of body protein going from late gestation to weaning. In addition, demands for milk production may have drawn more on body protein reserves than body fat stores. If the result of Brendemuhl et al. (1989) work with pigs is applicable to grazing sheep, one could speculate that quantity of forage intake was adequate to meet energy demands, but low protein quality of forage may have resulted in mobilization of body protein stores.

One other avenue of speculation may be that ewes having a lower body protein going into the fall and winter are better off energetically because of the lower metabolic energy cost of fat relative to protein. Rattray et al. (1974) reported that the cost of body protein synthesis requires 4.5 times more energy than fat synthesis (45.6 and 10.2 kcal ME per g, respectively). Therefore, energy needs for maintenance would be lower with a higher percent body fat tissue. In addition, Farrell and Williams (1989) found that after the first cycle of gain-loss, rats lost body weight more rapidly and regained that weight more quickly. During the final period, much of the weight gain was in the form of lean, but the majority of energy retained was as fat.

Implication

This paper focuses on the influence of nutritional management on body weight and composition. The results of our study indicate that although nutritional management systems may have a great impact on ewe body composition, the effects on lamb body weight are less severe. Further work is needed that incorporates economic and production entities into evaluation of nutritional management systems.

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Figure 1.Ewe nutritional management systems and temporal change in forage and feed resources.

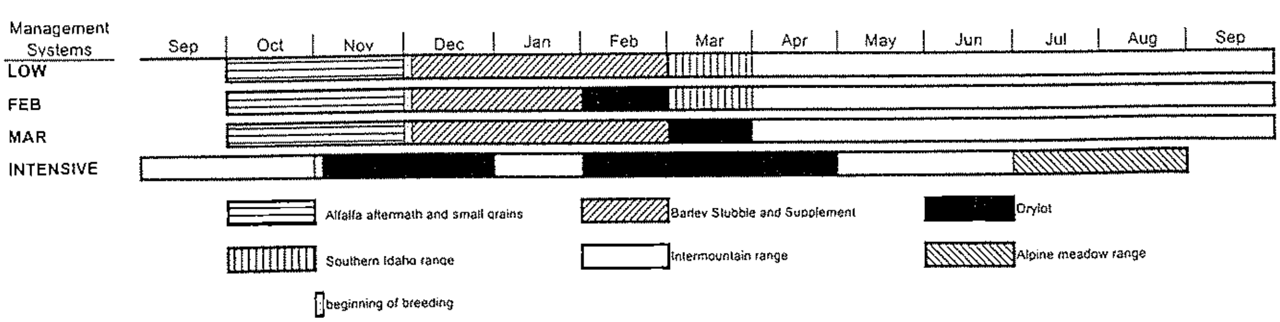

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Figure 2. Ewe nutritional management and single lamb body weight. Repeated measures analysis of nutritional management group, number of lambs reared, nutritional management group x lambs reared, and time x nutritional management group x lambs reared were significant ($P < .05$).[e]

[a] LOW, year around grazing
[b] FEB, 11 months grazing with drylot feeding in February
MAR, 11 month grazing with drylot feeding in March
[d] INTENSIVE, 8 months grazing with drylot feeding from November to December and February to April
[ef] Means within time lacking a common superscript differ ($P < .10$).

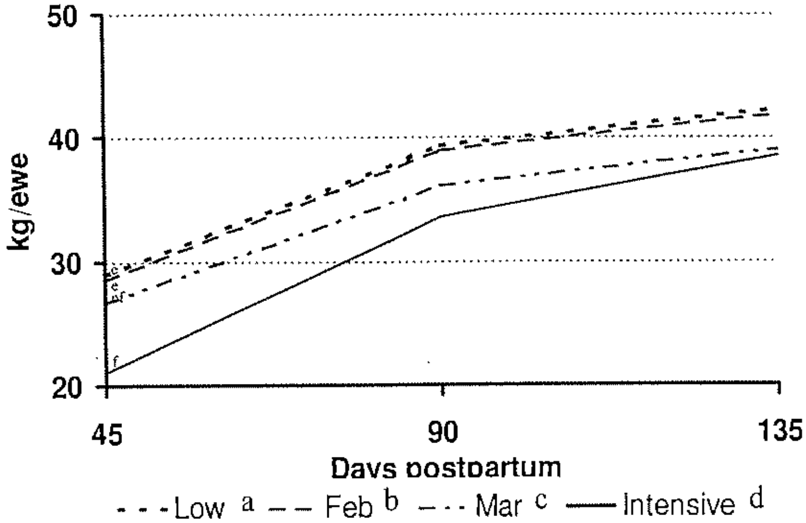
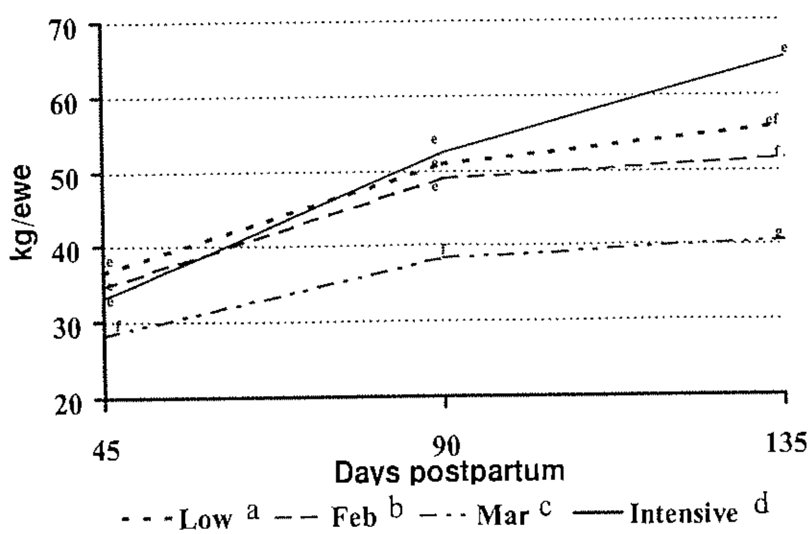


Figure 3. Ewe nutritional management and twin lamb body weight. Repeated measures analysis of nutritional management group, lambs reared, nutritional management group x lambs reared, and time x nutritional management group x lambs reared were significant ($P < .05$).[e]

[a] LOW, year around grazing
[b] FEB, 11 months grazing with drylot feeding in February
[c] MAR, 11 month grazing with drylot feeding in March
[d] INTENSIVE, 8 months grazing with drylot feeding from November to December and February to April



Research Briefs

Palatability of Chops from Calligpyge Lambs after Ultra-High Temperature Processing and Aging

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The benefits of increased lean meat yield and increased feed efficiency from callipyge sheep are tempered by concerns about unacceptable toughness of their chops, and the problem of toughness needs to be resolved before promoting use of callipyge animals in the lamb meat industry (for review see: Snowder and Carpenter, 1998). In this study, loin chops from callipyge lambs were processed in an ultra-high temperature (UHT) oven and aged at 2°C for 5 weeks. The UHT-treated and aged chops were cooked in a convection oven, and their palatability was evaluated by members of a consumer panel. UHT treatment was employed to allow for the extended aging of the chops. The high temperatures in the UHT oven pasteurize the surfaces of the meat to depths of about 2 mm, but the core of the meat remains raw and continues to undergo tenderization during refrigerated storage (Mendenhall, 1995). In preliminary experiments, shear values of UHT-treated lamb chops decreased with aging for up to 5 wk, but did not decrease further during the next 4 wk (unpublished data). Additionally, UHT processing may improve juiciness and flavor because the seared meat surface seals in juices and associated flavors during subsequent cooking, and(or) because UHT processing produces palatable grilled flavors on the meats surface (Mendenhall, 1995).

Ten callipyge ram lambs (approximately 58 kg live weight) were slaughtered at Utah State University under USDA inspection. The wholesale bone-in loins were removed from each carcass at 1 day after death. Each loin was cut in half and then into 2.54 cm-thick chops using a band saw. The chops were processed at 1100°C for 20 sec in an UHT oven (Mendenhall, 1995). The UHT-treated chops were vacuum packaged after a CO_2 flush, stored at 2°C for 5 wk, and then frozen for 4 months until they could be evaluated by a consumer panel. The chops were removed from the freezer, thawed at 2°C for 24 h, and the psoas muscle was cut from each chop and discarded. The chops were cooked, 8 at a time, at 185°C in a forced-air convection oven until the internal temperature was 68°C in a centrally-located chop. Sixty adults were recruited for the sensory testing of these chops. Judges had to be either fond of lamb or open-minded about sampling lamb to be included in the panel. The final panel composition was 28 males and 32 females. The panelists were served in shifts of no more than eight, each panelist receiving an entire chop on a heated plate within 15 minutes after the chop was removed from the oven. Panel members were instructed to evaluate the appearance of the chop and then eat part of it before beginning the evaluation of the other characteristics. Panelists had free access to salt and water during their evaluation. The chops were rated on a hedonic scale (1 = dislike extremely to 9 = like extremely) for appearance, juiciness, texture, flavor, and overall palatability. Panelists were also asked to indicate their likelihood to purchase, if available, lamb chops similar to the ones they had been served.

Most members of the consumer panel (52 of the 60 panelists, or 86%) moderately to very much liked the overall palatability of the callipyge chops that had been processed in the UHT oven and aged for 5 weeks (Table 1). Only two panelists

(3.3%) indicated that they would not be likely to purchase the UHT-treated and aged chops if they were available (data not shown in tabular form). These results suggest that UHT-treated and aged chops from callipyge lambs are more satisfactory to consumers than untreated or calcium chloride-injected chops from callipyge lambs, 40% and 15% of which, respectively, are unacceptable to consumers (Clare et al., 1997).

We believe that UHT treatment and aging were key factors that made the callipyge chops palatable, and we are presently employing this technique on all callipyge chops and racks sold from our university meat laboratory. Similarly, UHT treatment of lamb could be performed at the central facility of a lamb processor to realize an economy of scale that offsets the cost of a UHT oven. The chops and racks from all lambs could be processed through the UHT oven and aged, thereby avoiding the need to identify callipyge meat. UHT-treated meat provides convenience and quality because it can be cooked in a microwave and still have the flavors of grilled meat. The processor and retailer would also reap the benefit of an extended shelf life. The typical shelf life for beef in refrigerated storage is at least 10 weeks after UHT processing and vacuum packaging (Mendenhall, 1995). Thus, we expect that UHT-processed callipyge lamb could be aged for 5 weeks, part of which could be during the distribution cycle, and still have an additional 5 weeks of shelf life.

Acknowledgements

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Table 1. Sensory scores for UHT-processed, 5-week-aged chops from callipyge lambs.

Sensory Characteristic	Mean Score[a]	Number of panelists scoring sample "1", "2", or "3"[b]	Number of panelists scoring sample "4", ""5", or "6"[c]	Number of panelists scoring sample "7" "8", or "9"[d]
Appearance	7.5	1	5	54
Juiciness	7.6	0	5	52
Texture	7.0	1	14	45
Flavor	7.2	1	10	49
Overall palatability	7.3	0	8	52

[a]Mean hedonic score given to the chops by the panelists (n = 60).
[a]1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately
[c]4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly
[d]7 = like moderately, 8 = like very much, 9 = like extremely

Effects of Fish Meal and Sodium Bentonite on Daily Gain, Wool Growth, Carcass Characteristics, and Ruminal and Blood Characteristics of Lambs Fed Concentrate Diets

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Two experiments were conducted with Suffolk wether and ewe lambs to examine the effects of fish meal (FM) and sodium bentonite (NaB) in growing and finishing lamb diets based on corn, soybean meal, and cottonseed hulls. In Exp. 1, 15 lambs (9 wethers and 6 ewes) were assigned to three dietary treatments (13% CP (adequate) with or without 3% FM, and 11% CP (slightly deficient) with 3% FM) and fed for 92 d. In Exp. 2, 32 lambs (20 wethers and 12 ewes) were assigned to four isonitrogenous dietary treatments containing 13.5% CP, DM basis, and either 0% FM, 0% NaB; 0% FM, .75% NaB; 3% FM, 0% NaB; or, 3% FM, .75% NaB; and fed for 83 d. In experiment 1, lambs fed the diets containing 11% CP with 3% FM or 13% CP with 0% FM had similar dry matter intake and average daily gains. Gain and feed efficiency were slightly improved ($P = .18$) using the 13% CP diet containing 3% FM. In experiment 2, dry matter intake and average daily gains were increased (3.8 and 9.4%, respectively, $P < .05$) by FM and NaB supplementation. Diets containing FM produced higher ($P < .05$) gain: feed and heavier ($P < .05$) carcasses with greater ($P < .05$) body wall thickness. Total ruminal volatile fatty acids were increased ($P < .06$) by FM and NaB. The FM and NaB had only a slight influence on the mineral content of bone, liver, and kidney at the levels fed in this study. Neither FM nor NaB affected wool production, staple length, or fiber diameter. Similar improvements in DMI and ADG of lambs fed FM and NaB separately and in combination suggest that their individual beneficial effects are not additive at the levels fed in these diets. Consequently, it was recommended that FM and NaB should not be fed in combination because their modes of improvement appear to be similar.

-Prepared by C.J. Lupton

The Effect of Supplementation with Urea/Molasses Blocks on Sheep Reproduction on Small Farms in Chile

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Although providing supplemental feed to ewes at or around lambing is an established practice in the U.S., this is often difficult to do on small farms in some areas. This study involved six flocks of mainly Criolla (native) ewes in Southern Chile. Three of the six flocks received a supplement in the form of a block from approximately 50 prior to and 50 days after lambing. The other three flocks served as a control.

The block contained urea and molasses as well as a number of mineral elements. The average consumption was 45 grams per ewe per day. Body weights and condition score of the ewes were improved by block feeding as well as birth and weaning weights of their lambs. The market value of the additional lamb weight produced exceeded the cost of the block by a factor of 1.6:1. In addition, ewe lambs from the supplemented group reached sexual maturity and became pregnant at an earlier age.

-Prepared by Maurice Shelton

News and Notes

As the Sheep & Goat Research Journal enters its 15th year, a few changes have taken place. The Livestock Conservation Institute (LCI) now publishes the Journal, in cooperation with the American Sheep Industry Association (ASI). The changeover occurred at the completion of Volume 14, and LCI has been busy preparing to serve as the new home of the Journal. The Journal was established in 1984 through the Sheep Industry Development (SID) program and has been published by ASI ever since.

The aim of the Journal remains the same: to provide a peer-reviewed scientific publication of sheep and goat research findings which can be used by scientists, educators, veterinarians, extension agents and sheep and goat producers alike. LCI also remains committed to providing multi-disciplinary coverage. The Journal seeks to gather and distribute current research information on all phases of sheep and goat production including management, health, genetics, nutrition, reproduction, fiber, marketing and economics, and meat science, and to encourage producer use of research, which has practical application.

The Journal will be published by LCI under the guidance of the LCI Sheep Health Management Committee. Paul Rodgers will continue to serve as a technical advisor representing ASI and we are very pleased that Dr. Maurice Shelton, professor emeritus at Texas A&M University, will continue to serve as editor. We hope that the change will be seamless and little difference will be noticed. ASI and Paul Rodgers have done an outstanding job as publishers of the Journal and we hope to follow their lead.

Your input is welcomed. If you see something we can improve, let us know. The Journal office is equipped to take subscription orders, provide back issues of the Journal, and fulfill other needs. Manuscripts are currently being accepted. The Journal's publication coordinator is Bethanie Hargett-Slack.

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Sheep & Goat Research Journal

Guidelines for Authors

Objective

The aim of the Sheep & Goat Research Journal is to provide a peer-reviewed scientific publication of sheep and goat research findings which can be used by scientists, educators, veterinarians, extension agents and producers alike. The Journal is published three times each year by the Livestock Conservation Institute, in cooperation with the American Sheep Industry Association.

Editorial Policy

The Sheep & Goat Research Journal publishes 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 articles must represent unpublished original research, and conclusions reached must be supported by research results. Articles that promote commercial products or services will not be approved for publication. Articles that promote practical applied research are encouraged. The submission of review articles is accepted but will require the same review process as other submitted articles. At least one author of each submitted article must subscribe to the Journal. All manuscripts and correspondence should be addressed to Sheep & Goat Research Journal, P.O. Box 51267, Bowling Green, KY 42102-5567. Inquiries may be sent via electronic mail to sheep2goat@aol.com.

Review Process

Manuscripts will be subject to critical review by an editorial board or others designated by the editor. Authors will be notified by mail of acceptance or rejection of papers. Manuscripts needing revision will be returned to the corresponding author and should be revised and returned by the deadline indicated. Papers not suitable for publication will be returned to the corresponding author with a statement of reason for rejection. Consult the Sheep & Goat Research Journal *Editorial Policies and Procedures* for details of the technical requirements for manuscripts submitted to the Journal.

Manuscript Submission

Manuscripts should be mailed to the Sheep & Goat Research Journal, P.O. Box 51267, Bowling Green, KY 42102-5567. Five copies of each manuscript must be submitted. Each manuscript must be accompanied by a cover letter from the main corresponding author. The cover letter must include the mailing address, telephone and fax numbers, and e-mail address of the corresponding author. As a style reference, authors may refer to the Publication Manual of the American Physiological Association. Every effort is made to publish papers promptly. Normally, a paper is published approximately six months after it is received from the authors.

Format

Manuscripts must be typed and double-spaced. 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. When papers are accepted for publication, the authors must send a floppy disk with the manuscript in Microsoft Word format with two hard copies. Submission of excessive tabular data is discouraged; tables should be limited to that data that is considered essential to the research findings. Tables must be typed, double-spaced, and placed 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.

Please contact the Sheep & Goat Research Journal office to obtain a copy of the Journal's *Editorial Policies & Procedures* document for detailed formatting instructions.

The following format should be used when submitting research manuscripts:

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**

When 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." Please provide "interpretive summaries" for use by the sheep and goat industries in other media.

Proofing

Primary authors will receive galley proofs of articles for review. 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 asked to complete a reprint order form.

Charge

The publication charge for the Sheep & Goat Research Journal is $60.00 per page; position announcements are $30.00 per quarter-page or less. Authors will be billed after publication.

Sheep & Goat
Research Journal

Volume 15, Number 2: 1999

Contents:

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Sheep & Goat Research Journal
Volume 15, Number 2: 1999

Contents:

Treatment of Ovine Foot Rot Use of Florfenicol Versus Oxytetracycline for Treatment of Ovine Foot Rot [1,2]

S. Vandyke, L. Wallace, S.W. Sterle, J.A. Daniel, B.J. Holmberg, and D.H. Keisler

Summary

Contagious ovine foot rot is a devastating disease within the sheep industry. Greater treatment options and efficacy would enhance efforts to control foot rot. In this study, we sought to determine the efficacy of the recently introduced antibiotic florfenicol relative to oxytetracycline, a proven therapy for foot rot. At week = 0, 262 sheep, 1 to 5 years of age, received routine foot trimming and were randomly assigned to receive intramuscular injections on weeks 1 and 2 of saline (n = 87), florfenicol (20 mg/kg; n = 87), or oxytetracycline (20 mg/kg; n = 88). Feet were scored by two independent evaluators (blinded to treatments and to each other) for severity of infection on weeks 0, 1, 2, 3, and 6. Scores were assigned according to the Egerton and Roberts (1971) system using a scale of 0 to 4 with 0 denoting no foot rot and 4 denoting excessive foot rot. Data were analyzed using the GLM procedures of SAS. At week 0, mean foot rot score among all sheep was 2.05 ± .05. Mean foot rot score improved significantly among sheep treated with florfenicol or oxytetracycline vs. saline ($P<.01$). No difference in foot-rot score existed between sheep treated with florfenicol or oxytetracycline. Mean foot-rot scores were significantly lower following the second injection of antibiotic than the first. On week 6 average foot-rot scores were 0.56 ± 0.06, 0.66 ± .08, and 1.79 ± .09 for florfenicol, oxytetracycline, and saline treated ewes, respectively. We suggest that these data provide evidence that florfenicol and oxytetracycline were equally effective in reducing the severity of foot rot among ewes.

Keywords: Foot rot, oxytetracycline, florfenicol

Introduction

Contagious ovine foot rot is a significant cause of economic loss within the sheep industry (Marshall et al., 1991). Early symptoms of foot rot, known as "foot scald", can be attributed to infection by Fusobacterium necrophorum; a gram-negative bacteria that is naturally present in the anaerobic environment of the sheep intestine (Tan et al., 1997). Once outside of the intestine, Fusobacterium necrophorum can survive for 7 to 14 days. It is during this time that the bacteria can establish residence in the skin of the inter-digital region of the hoof and begin producing endotoxins and leukotoxins, which result in local interdigital and coronary band lesions. Exposure of the weakened and lesioned areas to Dichelobacter nodosus, a gram-negative anaerobic bacteria, aggravates hoof inflammation (Tan et al., 1997). Ultimately, the potent proteases produced by Dichelobacter nodosus permit the bacteria to penetrate and infect the horn of the hoof. If left untreated, separation of the hoof wall can occur resulting in chronic foot rot and occasionally death of the animal (Ware et al., 1994).

Typically, sheep contract Dichelobacter nodosus from other foot-rot infected sheep or fomites such as contaminated hoof trimmers. Therefore, producers are encouraged to practice preventive measures to avoid the problem of foot rot, since most treatment and eradication methodologies are labor intense and vary in efficacy. Use of antibiotics such as oxytetracycline to treat sheep with foot rot has been practiced for years, but the therapeutic response is often short-lived (Grogono-Thomas et al., 1994). Recently,

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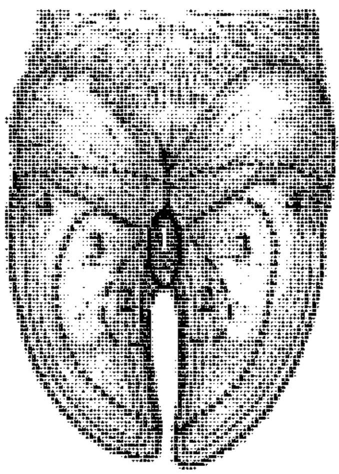
Figure 1. Egerton and Roberts (1971) system of classifying severity of foot rot inflammation (adapted from Egerton *et al.*, 1989)



Egerton-Roberts Foot Scoring

Scoring System

0 = No Inflammation present.
1 = Inflammation is confined to the interdigital skin.
2 = Severe inflammation of the interdigital skin.
3 = Inflammation penetrates the hoof.
4 = Inflammation penetrates hoof and abaxial margin at the wall of the hoof.

the FDA approved the use of florfenicol for treatment of bovine respiratory disease. Use of florfenicol in sheep however remains "extra-label" and legal only if no other approved drug is more effective.

Florfenicol is a synthetic, broad-spectrum, fluorinated derivative of thiamfenicol, which is a member of the chloramphenicol antibiotic family (Lobell et al., 1994). Chloramphenicols have been banned from use in food animals, due in part to their potential for causing fatal aplastic anemia in humans. Of interest, it has been determined that bacteria that carry a chloramphenicol-resistance plasmid, are susceptible to florfenicol. The objective of this study was to compare the efficacy of florfenicol vs. oxytetracycline vs. saline for the treatment of contagious ovine foot rot.

Materials and Methods

Two hundred and sixty-two sheep of varying breeds and ages ranging from 1 to 5 years, were used in this study. At week 0 the sheep's hooves were trimmed according to routine management guidelines. Severity of infection in each foot was scored by two independent evaluators (blinded to treatments and to each other) using the Egerton and Roberts system (1971; Figure 1). Scores were ranked on a scale of 0 to 4 with sheep scoring 0 considered free of inflammation. When inflammation was confined to the interdigital skin, a score of 1 was assigned and increased to 2 if the inflammation was severe. A score of 3 was assigned to inflamed hooves where the keratinized horny portion of the hoof was involved. If the inflammation extended to the abaxial margin of the walls of the hoof, then a score of 4 was assigned. Each time the feet were scored, hooves were trimmed sufficient only to permit an accurate score to be assigned.

Following hoof trimming at week 0 (see Figure 2), sheep were randomly assigned to one of three treatment groups designated as: oxytetracycline (n = 88), florfenicol (n = 87), or saline (n = 87) treated animals. Oxytetracycline (LA-200®; Pfizer Animal Health, New York, NY) was administered as an intramuscular injection of 20 mg/kg bodyweight per animal. Florfenicol (Nuflor®; Schering-Plough Animal Health; Kenilworth, NJ) was administered as an intramuscular injection of 20 mg/kg bodyweight per animal. An equivalent volume of saline was injected intramuscularly to simulate the florfenicol and oxytetracycline treatments.

Throughout the trial, sheep were managed as a single flock on a single pasture and received injections of antibiotic or saline on weeks 1 and 2, at which time foot scores were assessed. On weeks 3 and 6, foot scores were again assessed. Data were analyzed using the GLM procedures for SAS (SAS 1985). Means separation procedures were preformed using a Student-Newman-Kuels test where appropriate.

Results and Discussion

Average foot scores among sheep at weeks 0 and 1 were 2.05 ± 0.05 and 2.32 ± .09, respectively, and did not differ with respect to group ($P > 0.10$; Figure 3). By weeks 2, 3, and 6, mean foot scores improved significantly among all sheep ($P < 0.05$), particularly those treated with oxytetracycline (0.87 ± 0.11, 0.14± 0.07 and 0.66 ± 0.08) or florfenicol (0.67 ± 0.12, 0.12± 0.07 and 0.56 ± 0.06) versus saline (1.38 ± 0.09, 1.13 ± 0.08 and 1.79 ± 0.09; $P < 0.01$). The improvement of foot scores following week 1 among saline treated sheep has been described as "self-cure" (Jordan et al., 1996). However, why a similar improvement in foot condition was not observed following week 0 is not known; perhaps the effects of minimal foot trimming are not evident until 2 weeks following last paring. It has also been reported that trimming the hooves of sheep treated with antibiotics did not contribute to improved foot scores (Jordan et al., 1996). Our data do not support this report, but rather the improved foot conditions among sheep at weeks 2 and 3 (after the first and second injections, respectively), exceeded that attributable to "self cure" associated with minimal foot trimming. At no time during the study did foot condition scores differ between florfenicol and oxytetracycline treated sheep ($P > 0.10$). The improved foot conditions among the antibiotic treated sheep vs. saline treated sheep persisted for at least 4 weeks following the last injection of antibiotic.

We concluded from these data that florfenicol and oxytetracycline had a significantly beneficial effect on improving foot health scores ($P < 0.01$). Relative to other treatments, investigators have reported that use of a long acting oxytetracycline was more effective than treating ewes with 10% Zinc sulphate foot baths for one hour, four days apart (Grono-Thomas et al., 1994). Furthermore, an intramuscular injection of oxytetracycline was also shown to result in a larger percentage of cured sheep than either a penicillin - streptomycin mixture or a lincomycin - spectinomycin mixture (Jordan et al., 1996).

Conclusions

Once foot rot is established in a flock of sheep, foot health begins to deteriorate. In the current study, inflammation was most progressive among sheep not receiving antibiotics. Treatment of sheep with antibiotics augmented the improvement in foot health associated with foot trimming and allowed the improved foot health to persist for at least 4 weeks following last injection of antibiotic. Use of florfenicol to manage foot health however did not differ in efficacy from oxytetracycline. Consequently, because florfenicol proved no more effective than oxytetracycline in treating foot rot, its use as an "extra-label" application for this condition cannot be justified.

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Figure 2. Sequence of conducting the experimental protocol. On weeks 1 and 2, sheep received an intramuscular injection of saline or 20mg/kg body weight of florfenicol or oxytetracycline.

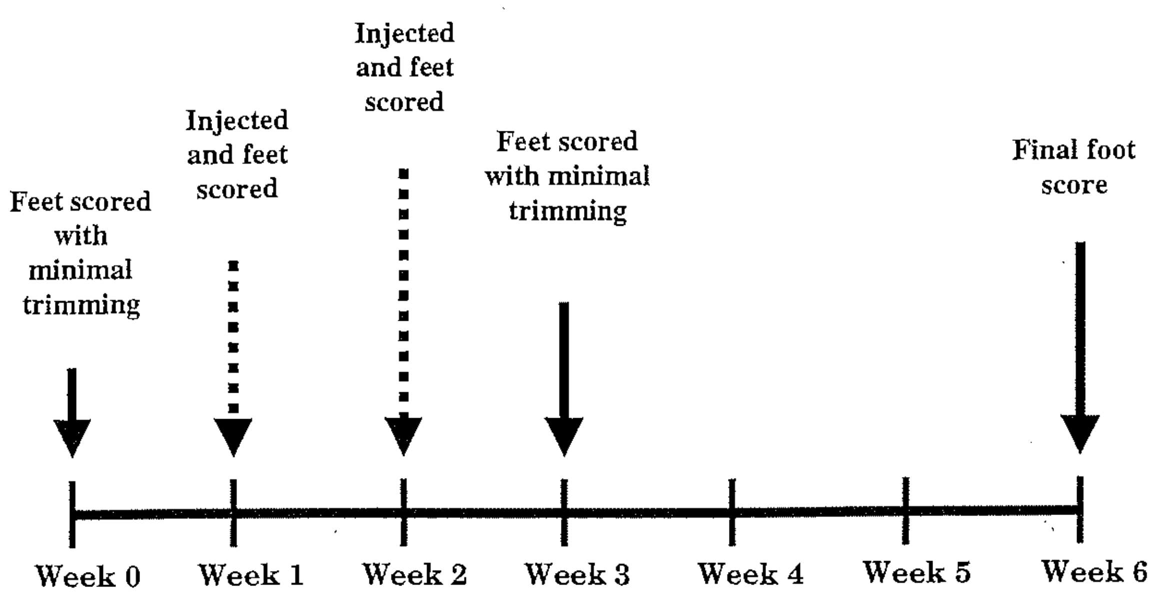

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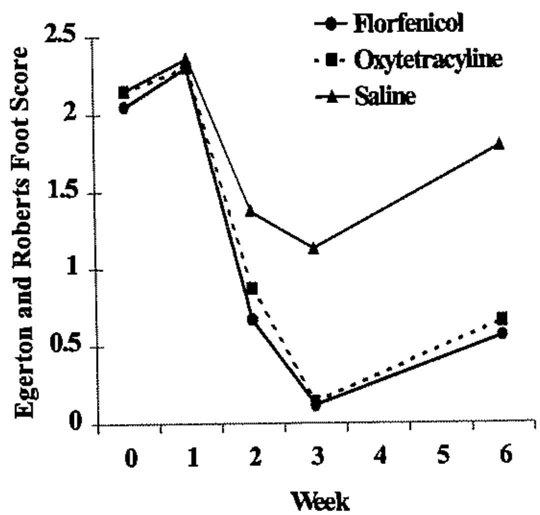
Figure 3. Foot rot scores over time among sheep treated with an injection of saline, florfenicol (20mg/kg body weight) or oxytetracycline (20mg/kg body weight) on weeks 1 and 2. Superscripted letters denotes differences across treatment-within-week of assessment.



Comparison of Reproductive Performance of Crossbred Ewes Maintained as a Fall or Spring Lambing Flock at Two Different Locations: Fertility, Prolificacy, and Litter Weight Weaned[1]

T. P. Lundeen[2] and A. L. Slyter[3]

Summary

Reproductive performance of 524 1/4-Finn x 1/4-Dorset x 1/2-Targhee (FDT) and 80 Hampshire x FDT ewes managed as a fall or spring lambing flock in either a range or farm flock system were evaluated for ewe fertility, prolificacy, lambs born and weaned per ewe exposed, lambs weaned per ewe lambing, and litter weight weaned per ewe lambing adjusted to 75 days of age. Data included 1,781 ewe exposures resulting in 2,180 lambs born.

Improvement was found for most traits as age of ewe increased within the same location and ewes lambing in the spring performed better than their contemporaries in the fall. Also, farm flock ewes tended to perform better than range flock ewes of the same age and lambing season.

In the farm flock system as ewe age increased, the difference between ewes lambing in the fall and those lambing in the spring decreased, indicating that progress can be made to improve the reproductive performance of the fall lambing ewes.

The use of a separate fall lambing group is feasible for spreading lamb production out through the year, especially with the use of mature animals. If each lambing group is uniquely identified, the two groups could be commingled for much of the year to make best use of feed and labor resources. Lambing facilities, which are traditionally used only once per year, will be utilized twice annually, spreading overhead costs out over the two groups.

Key Words: ewe, lambing season, fertility, prolificacy, litter weight

Introduction

One of the goals of any sheep operation is to optimize the use of facilities and labor while spreading costs over as many marketable lambs as possible. To accomplish this, shortened interval lambing systems have been introduced that can increase the number of lambing opportunities to 1.3 or 1.5 per ewe per year in an effort to increase the pounds of weaned lamb per ewe exposed per year (SID, 1988). One disadvantage to many of these systems is the large amount of time and labor needed to make these operations run successfully.

The length of time since the last lambing and the current breeding exposure can impact the fertility of ewes during the spring breeding season. Lewis et al. (1996) found that ewes bred during the spring months following a short postpartum interval resulted in a less fertile mating than when ewes were bred during the same period following a long postpartum interval. This would suggest that ewes would be more fertile during spring breeding if they had a longer rest period between the previous lambing and the next breeding period as would be the case for ewes given only one breeding opportunity per year.

In addition, in order to improve fertility in the spring breeding season selection for fertile ewes in the spring is necessary. Al-Shorepy and Notter (1996) demonstrated that the heritability estimates for fertility for fall lambing were higher than estimates reported for spring lambing groups. Therefore, selection to improve fertility may be more effective in fall lambing ewes than in spring lambing ewes . Ewes that produced large litters in the fall were above average in genetic merit for spring fertility. Thus, litter size of fall-lambing ewes was found to be favarably correlated to the ewes' fertility during the spring months, making this trait a useful

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selection criterion to improve fertility in spring breeding (Al-Shorepy and Notter, 1996).

An alternative to short interval lambing is to divide the flock into two distinct lambing groups - one to breed in the spring and lamb in the fall and the other to be mated in the fall and lamb in the spring. In this system, individual ewes only lamb once per year but lamb production occurs over more of the year and provides increased market opportunities. Since lambing occurs at approximately the same calendar dates each year, management of the two groups is less complicated than in the shortened interval systems. The use of equipment, facilities, and labor as well as costs and risk are more efficiently spread out over more of the year.

Fall lambing ewes can complement a winter or spring lamb production system. Selecting for fertility in the fall lambing group should improve the success of this system. The objective of the current study was to measure the performance of crossbred ewes lambing in the fall compared to similar ewes lambing in the spring at two different locations representing common lamb production systems found in South Dakota.

Materials and Methods

Finn-Dorset x Targhee (FDT) F_1 (n=524) and Hampshire x FDT (n=80) ewe lambs produced at the Antelope Range Livestock Station (Buffalo, SD) in 1992, 1993, and 1994 were the base flock of this study. These April-born ewe lambs were weaned in August-September and transported to the Brookings Station where they were grown out and exposed at approximately 12 months of age for September lambing. All available ewe lambs were exposed with no prior selection. Each year the pregnant ewes from this initial exposure were randomly assigned to either the range or farm flock fall lambing group. The remaining open ewes were randomly split among the two fall lambing groups and the two spring lambing groups to balance the numbers per group, i.e., approximately 50 ewes entering the fall and spring groups in the range and farm flock systems each year for three years. Subsequent replacement ewes were selected from multiple births from early lambing ewes and remained with their birth group starting with the fall 1994 group of lambs (fall born ewe lambs remained with the fall group and spring born ewe lambs remained with the spring group). Rams were selected from only the fall lambing groups at both locations and used as yearlings for one year in both fall and spring breeding at their respective locations. Only fall born rams were used in order to reduce the total number of rams needed to be maintained at any point in time. Any bias this might introduce would be expected to favor the spring lambing groups and therefore not impact selection for spring breeding ability. Rams were replaced annually and the ewes were turned over as rapidly as possible while maintaining base flock numbers.

Management practices common to all groups included the use of teaser rams for 15 days prior to exposure to fertile rams, flushing, a 35-day breeding season, and routine vaccinations. Ewes remained with their lambing group throughout the trial. Ewes were culled if they missed two consecutive lambings or were functionally unsound. After the flock size was established, ewe turnover was as rapid as possible with approximately one third of the ewes being replaced each year. Each flock was maintained at approximately 150 head at each lambing opportunity.

The spring farm flock ewes were exposed to fertile rams starting approximately September 20 at Brookings and the spring range flock ewes starting approximately November 15 at the Antelope Range Livestock Station. Ewes in both fall flocks were exposed beginning approximately April 15.

At lambing, number of lambs born (live and dead), sex of lamb, and individual lamb birth weights were recorded. Ewes were allowed to raise no more than two lambs. Extra lambs were either grafted onto another ewe or sold if no graft dam was available. All male lambs were castrated, in both spring lambing groups, while in the fall groups sufficient lambs were left intact to select 10 to 12 male ram lambs as possible ram replacements. Ram lambs were selected from early born multiple birth litters. Lamb weights at weaning were recorded and adjusted to a common 75 days of age. No adjustments were made for lamb sex, age of dam, or type of birth/rearing in order to more accurately reflect actual weight of lamb produced. Numbers of ewes exposed and lambing were also recorded.

Percentage of ewes lambing (fertility), lambs born and weaned per ewe lambing and per ewe exposed, and litter weight weaned per ewe lambing adjusted to 75 days of age were analyzed using repeated measures procedures of PROC MIXED of SAS (1996). The model used was $Y = \mu$ + location + season + ewe age + location x season + location x ewe age + season x ewe age + location x season x ewe age + ε. Least squares means from the highest order interaction are reported in all cases regardless of statistical significance, since they have the most biological meaning. Least squares means for main effects and other interaction effects are not reported because of empty cells caused by an uneven distribution of animals in the older ewe age groups.

Each group was exposed a minimum of four breeding seasons, therefore no fall groups contained 5-year-old ewes. Ewes were not exposed as lambs in the range breeding groups.

Results and Discussion

Fertility

Least squares means and standard errors for ewe fertility and prolificacy are presented in Table 1. Within location x season groups, fertility improved as age increased in the fall lambing groups, with the exception of yearling fall range ewes, but did not change in the spring lambing groups. The management practice of culling ewes that missed lambing for two consecutive years resulted in more attrition of ewes in the lower fertility group, i.e., fall range group. Therefore, only four 4-year-old ewes were present at mating for this group compared to 25 for the fall farm group. This management practice should also increase the fertility level observed for the remaining ewes. Comparing similar aged ewes in the fall lambing season indicated that farm flock ewes were more fertile than range flock ewes. Fertility for fall lambing increased with increasing age of the ewe in both the range and farm groups. However, the resulting fertility (40.9%) level for the 4-year-old fall range group is still too low for producer adoption. Under practical production systems it would be advisable to re-expose the open fall ewes for lambing the subsequent spring. However, in this selection study, ewes were not allowed to move from one lambing season to another to avoid confounding effects. In the spring groups there was no difference in fertility between range and farm flock ewes. Between seasons, range fall ewes were less fertile than range spring ewes of similar ages. In the farm fall groups, ewes aged 1 or 2 years were less fertile than their contemporaries in the spring (age 1 P-value < 0.001; age 2 P-value < 0.001) while at higher ages there was no difference in fertility between the fall and spring ewes (age 3 P-value = 0.317, age 4 P-value = 0.547).

Prolificacy

Within the location x season groups, prolificacy did not change in either range fall or range spring groups as age increased (Table 1). However, prolificacy improved with each increase in age in the farm fall and farm spring groups. In the fall lambing systems, there was no difference between similar aged ewes in the range system and the farm system. In the spring lambing groups, however, the farm group had more lambs born per ewe lambing at each age than the range spring ewes (Table 1). In the range system, ewes lambing in the spring had more lambs born per ewe lambing as a 2 year old than contemporaries lambing in the fall (1.80 ± 0.047 vs 1.44 ± 0.123, P = .006) and at age 3 (1.89 ± 0.051 vs 1.52 ± 0.175, P = 0.043) but were similar at age 4 (1.93 ± 0.062 vs 1.47 ± 0.352, P = 0.221). In the farm system,

Table 1. Least squares means (LSM ± SE) for ewe fertility and prolificacy by age of ewe, lambing season, and location[a].

	Range			Farm			P-values range vs farm	
Age	n	Fertility	Prolificacy	n	Fertility	Prolificacy	Fertility	Prolificacy
			Fall Lambing					
1	156	74.2 ± 2.87[b]	1.23 ± 0.049[b]	282	66.0 ± 2.14[b]	1.22 ± 0.039[b]	0.022	0.954
2	175	10.4 ± 2.72[c]	1.44 ± 0.123[b]	209	69.1 ± 2.51[b]	1.38 ± 0.045[c]	<0.001	0.639
3	54	14.4 ± 4.74[c]	1.52 ± 0.175[b]	70	82.6 ± 4.21[c]	1.55 ± 0.068[d]	<0.001	0.882
4	4	40.9 ± 17.4[bc]	1.47 ± 0.372[b]	25	98.6 ± 7.04[d]	1.88 ± 0.105[e]	0.002	0.296
			Spring Lambing					
1	—	—	—	102	92.3 ± 3.52[b]	1.30 ± 0.054[b]	—	—
2	145	88.4 ± 2.97[b]	1.80 ± 0.047[b]	171	92.5 ± 2.74[b]	1.94 ± 0.042[c]	0.318	0.028
3	113	93.5 ± 3.35[b]	1.89 ± 0.051[b]	101	88.0 ± 3.53[b]	2.26 ± 0.055[d]	0.260	<0.001
4	77	93.2 ± 4.06[b]	1.93 ± 0.062[b]	65	93.9 ± 4.41[b]	2.48 ± 0.067[e]	0.902	<0.001
5	29	96.6 ± 6.54[b]	2.01 ± 0.099[b]	8	98.4 ± 12.4[b]	2.64 ± 0.185[e]	0.893	0.003

[a] The location x season x ewe age interaction for prolificacy was not significant (P = 0.7988).
[b,c,d,e] Least squares means within location x season group lacking similar superscripts are different (P < 0.05).

fall and spring ewes only had similar prolificacy as yearlings (farm fall yearlings 1.22 ± 0.039 vs farm spring yearlings 1.30 ± 0.054, $P = 0.260$).

Lamb Production Per Ewe Exposed

Lambs born and weaned per ewe exposed combines fertility and prolificacy with mothering ability and gives an indication of the total productivity of the ewe flock. Least squares means and standard errors for these two traits are presented in Table 2.

Management system affected lamb production per ewe exposed. Farm flock ewes gave birth to more lambs per ewe exposed than range ewes at all ages except yearling fall lambing ewes (range fall 1 = 0.91 ± 0.056, farm fall 1 = 0.81 ± 0.042, $P = 0.149$). Fertility seems to have a greater impact on this trait than prolificacy, as a ewe that does not lamb actually lowers the average more than a ewe with twins can raise the average.

Season also impacted lamb production on a ewe exposure basis. Spring ewes in both the range and farm systems gave birth to more lambs per ewe exposed than fall ewes of the same age. Spring lambing ewes also weaned more lambs per ewe exposed than fall ewes in the range system at all ages and in the farm system at all ages except 4 year olds (farm fall 4 = 1.49 ± 0.130 vs farm spring 4 = 1.64 ± 0.081, $P = 0.344$).

Within the location x season groups, range ewes in spring improved in both traits from age 2 compared to 3, but no improvement was noted as age increased further. Range fall lambing ewes had significantly higher production at age 1 compared to age 2 and then began to improve with each productive cycle so that by age 4 performance in both traits was intermediate to the yearlings and 2 to 3 year olds. Both the higher fertility (table 1) and higher number of lambs per ewe exposed (table 2) for yearling fall range ewes is the result of initial allotment of spring born ewes which were 18 months old at first lambing and therefore labeled as yearlings, since no ewe lambs were exposed

Table 2. Least squares means (LSM ± SE) for number of lambs born and weaned per ewe exposed by age of ewe, lambing season, and location[a].

	Range			Farm			P-values range vs farm	
Age	n	Lambs born per ewe exposed	Lambs weaned per ewe exposed	n	Lambs born per ewe exposed	Lambs weaned per ewe exposed	Lambs born per ewe exposed	Lambs weaned per ewe exposed
Fall Lambing								
1	156	0.91 ± 0.056^{b}	0.81 ± 0.053^{b}	282	0.81 ± 0.042^{b}	0.63 ± 0.039^{b}	0.149	0.007
2	175	0.15 ± 0.053^{c}	0.13 ± 0.050^{c}	209	0.95 ± 0.049^{c}	0.84 ± 0.046^{c}	<0.001	<0.001
3	54	0.23 ± 0.093^{c}	0.24 ± 0.087^{c}	70	1.29 ± 0.082^{d}	1.13 ± 0.078^{d}	<0.001	<0.001
4	4	0.63 ± 0.343^{bc}	0.66 ± 0.325^{bc}	25	1.86 ± 0.138^{e}	1.49 ± 0.130^{e}	<0.001	0.017
Spring Lambing								
1	—	—	—	102	1.20 ± 0.069^{b}	1.05 ± 0.065^{b}	—	—
2	145	1.59 ± 0.058^{b}	1.21 ± 0.055^{b}	171	1.80 ± 0.054^{c}	1.57 ± 0.050^{c}	0.009	<0.001
3	113	1.77 ± 0.066^{c}	1.49 ± 0.062^{c}	101	2.00 ± 0.069^{d}	1.55 ± 1.64^{c}	0.016	0.548
4	77	1.81 ± 0.079^{c}	1.48 ± 0.075^{c}	65	2.34 ± 0.086^{e}	1.64 ± 0.081^{c}	<0.001	0.144
5	29	1.94 ± 0.128^{c}	1.47 ± 0.121^{c}	8	2.62 ± 0.243^{e}	1.58 ± 0.230^{c}	0.014	0.661

[a] The location x season x ewe age interaction for lambs born per ewe exposed was not significant ($P = 0.3768$).

[b,c,d,e] Least squares means within location x season group lacking similar superscripts are different ($P < 0.05$).

for lambing at 12 months of age in this group.

In the farm system, increases in performance for lambs born per ewe exposed were noted as age increased in both fall and spring groups. Lambs weaned per ewe exposed also improved with age for the fall lambing group, but in the spring there was only improvement between ages 1 and 2.

Most researchers have not evaluated lamb production per ewe exposed. Iman and Slyter (1996) reported farm and range flock ewes lambing in the spring gave birth to similar numbers of lambs per ewe exposed, contrasting the results found in the current study.

Lambs Weaned Per Ewe Lambing

Lambs weaned per ewe lambing adds a measure of mothering ability and lamb viability to prolificacy. Least squares means and standard errors for lambs weaned per ewe lambing are presented in Table 3. Trends for lambs weaned per ewe lambing are similar to prolificacy.

When comparing lambs born and lambs weaned per ewe lambing, ewes lambing in the fall tended to wean a greater percentage of their lambs than the spring lambing ewes, even though the spring ewes were giving birth to and weaning more total lambs. This may be due to a more favorable environment and/or lower prolificacy for lambs reared in the fall compared to February (farm flock) or April (range flock). In South Dakota, fall temperatures are milder, resulting in a decrease in the incidence of young lamb hypothermia and/or illnesses (pneumonia, scours) caused by inclement environmental conditions.

Litter Weight Weaned Per Ewe Lambing Adjusted to 75 Days of Age

Litter weights were taken at weaning and adjusted to a common 75 days of age. Adjustments were not made for lamb sex, birth type, rearing type, or age of dam in order to be more reflective of actual weight of lamb available to market. Weights were adjusted for age to account for the vari-

Table 3. Least squares means (LSM ± SE) for lambs weaned per ewe lambing[a] and litter weight weaned per ewe lambing adjusted to 75 days of age by age of ewe, lambing season, and location[b].

	Range			Farm			P-values range vs farm	
Age	n	Lambs weaned per ewe lambing	Litter wt weaned per ewe lambing, kg	n	Lambs weaned per ewe lambing	Litter wt weaned per ewe lambing, kg	Lambs weaned per ewe lambing	Litter wt weaned per ewe lambing
Fall Lambing								
1	156	1.14 ± 0.041^{c}	23.3 ± 0.977^{c}	282	1.13 ± 0.035^{c}	29.3 ± 0.812^{c}	0.816	<0.001
2	175	1.29 ± 0.106^{cd}	25.0 ± 2.48^{c}	209	1.30 ± 0.035^{d}	34.8 ± 0.891^{d}	0.916	<0.001
3	54	1.55 ± 0.145^{d}	28.0 ± 3.41^{c}	70	1.50 ± 0.059^{e}	40.5 ± 1.39^{e}	0.738	<0.001
4	4	1.49 ± 0.308^{cd}	25.3 ± 7.23^{c}	25	1.72 ± 0.093^{f}	45.5 ± 2.18^{e}	0.471	0.008
Spring Lambing								
1	—	—	—	102	1.20 ± 0.046^{c}	29.9 ± 1.08^{c}	—	—
2	145	1.55 ± 0.041^{c}	36.5 ± 0.963^{c}	171	1.79 ± 0.036^{d}	45.6 ± 0.836^{d}	<0.001	<0.001
3	113	1.67 ± 0.043^{d}	38.1 ± 1.01^{c}	101	1.81 ± 0.046^{d}	47.4 ± 1.09^{d}	0.027	<0.001
4	77	1.68 ± 0.053^{cd}	37.9 ± 1.24^{c}	65	1.80 ± 0.056^{d}	46.1 ± 1.32^{d}	0.114	<0.001
5	29	1.66 ± 0.085^{cd}	37.0 ± 2.00^{c}	8	1.86 ± 0.165^{d}	45.0 ± 3.86^{d}	0.281	0.068

[a] The location x season x ewe age interaction for number of lambs weaned per ewe lambing adjusted to 75 days was not significant ($P = 0.6529$).
[b] The location x season x ewe age interaction for litter weight weaned per ewe lambing adjusted to 75 days of age was not significant ($P = 0.3901$).
[c,d,e,f] Least squares means within location x season group lacking similar superscripts are different ($P < 0.05$).

ability of weaning ages between different lambing groups. Least squares means and standard errors for litter weight weaned per ewe lambing adjusted to 75 days of age are presented in Table 3.

Within the range flocks, litter weight at 75 days did not change as age of ewe increased. However, in the farm fall group, litter weight increased approximately 5 kg per ewe lambing per year (for a total of 16.2 more kg for 4-year-old ewes over yearlings). These increases were significant except between ages 3 and 4. Total increase in weaned lamb weight was similar in the farm spring group, except these ewes had an increase of 15.7 kg between ages 1 and 2 followed by no significant differences between the older ages.

In the range management system, fall 2-year-olds had significantly less weight of lamb weaned (25.0 ± 2.48 vs 36.5 ± 0.963 kg, $P < 0.001$) compared to spring 2-year-olds, while there was no difference between the season groups on the range at the older ages. In the farm management system, yearlings in the fall and spring had similar weights weaned (farm fall 1 = 29.3 ± 0.812 vs farm spring 1 = 29.9 ± 1.08 kg, $P = 0.687$). Four-year-old ewes also had similar litter weights at weaning between farm fall (45.5 ± 2.18 kg) and farm spring (46.1 ± 1.32 kg, $P = 0.804$).

Conclusions

Productivity of ewes managed, as a fall lambing flock was lower than that of a spring lambing flock in both the range and farm management systems. However, with age, productivity of the fall lambing ewes approached, if not matched, the productivity of similar aged ewes in the spring flocks. Fertility of the fall lambing ewes, especially in the range system, was of most concern. If these ewes fail to produce a lamb, there would be no economic compensation returned to the system. In most cases, as mentioned previously, in normal production situations open ewes from one lambing group would be re-exposed with the next breeding group and thereby reduce the number of open days compared to what occurred under the experimental design of this study. The current study demonstrated that with time, maintaining a separate ewe flock lambing in the fall can be a viable alternative to traditional spring-only lambing and to the more complicated shortened interval lambing systems. Results indicated that the fall system was better suited for the farm flock management system.

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Effect of Short-Term Protein Supplementation on Colostrum Characteristics and Immunoglobulin G Concentrations in Colostrum and Ewe and Lamb Serum[1]

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Summary

Twenty-six Rambouillet ewes pregnant with twins were assigned to three dietary treatments to evaluate effects of short-term protein supplementation during late gestation on colostrum production and immunoglobulin G (IgG) concentrations. Ewes were individually fed either 85% (n = 9), 100% (n = 10), or 115% (n = 7) of their crude protein (CP; soybean meal) requirements on a body weight (BW) basis during the last 24 ± 2.6 days (mean ± SD) of gestation. Ewes were fed grass hay and received corn to make diets isocaloric. Ewes were milked with an Alfa Laval Agri Sheep Milker within 1 hour following parturition and every 6 hours for 24 hours. Ewe blood and colostrum samples were obtained at each milking. Blood samples were obtained from lambs within 30 minutes of their dam's blood/colostrum collection period and at 1, 3, 6, 9, 12, 15, 18, and 24 hours later. Lambs were tube-fed their dam's colostrum (30 g/kg of BW) within 30 minutes after birth of the second lamb, at 3-hour intervals for 12 hours and at 18 hours. At parturition (hour = 0; prepartum accumulation), colostrum production was greater ($P = 0.06$) for ewes receiving 115% CP than ewes receiving either 100% or 85% CP. Total colostrum accumulation (sum of hours 6–24) postpartum was not affected ($P = 0.20$) by protein intake. Ewes consuming 115% CP had greater ($P = 0.10$) concentrations of IgG in colostrum than ewes consuming 85% CP. Ewes supplemented with 85% CP lost more ($P = 0.04$) weight than ewes receiving either 100% or 115% CP. Lamb birth weights did not differ ($P = 0.20$) among treatments, however, lambs produced by ewes receiving 115% CP tended ($P = 0.12$) to have heavier weaning weights. These results suggest that feeding 115% CP for approximately 3 weeks before parturition increased prepartum colostrum accumulation, enhanced IgG concentrations in the colostrum, and improved animal performance.

Key words: sheep, protein supplementation, lactation, immunoglobulin

Introduction

Colostrum supplies an abundant source of nutrients and immunoglobulins for the newborn. The requirements for colostrum are closely related to number of lambs born (Hall et al., 1992), but even lambs born with replete energy reserves may die of starvation if supply of colostrum is inadequate (Mellor, 1983). Additionally, an insufficient accumulation of colostrum deprives the newborn lamb of immunoglobulins which help provide protection against disease (Mellor, 1988). Therefore, management methods that improve colostrum accumulation could be one avenue of improving neonatal survival during the first week following birth.

Rapid mammary growth and colostrum accumulation begins 2 to 3 weeks before parturition in the ewe (Mellor and Murray, 1985a). Consequently, increasing nutrition at this time may improve the production of colostrum. Mellor and

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Table 1. Chemical composition of dietary ingredients and percentage of ingredients fed ewes receiving three levels of crude protein supplementation.

	Dietary ingredients		
Item	Grass hay	Soybean meal	Corn
Dry Matter, %	92.3	90.6	86.0
CP[a]	9.9	49.4	8.7
NDF[b]	66.1	26.5	44.4
ADF[c]	36.9	6.1	3.4
ADIN[d]	8.9	2.9	7.9
Ash	13.0	7.2	1.2
	Treatments[e]		
Ingredients	85%	100%	115%
Grass hay	66	65.6	66.1
Corn	34	31.2	26.3
Soybean meal		3.2	7.6

[a]CP = crude protein.
[b]NDF = neutral detergent fiber.
[c]ADF = acid detergent fiber.
[d]ADIN = acid detergent insoluble nitrogen.
[e] Treatment: 85% (n = 9), 100% (n = 10), and 115% (n = 7) of their crude protein requirements on a dry matter basis.

Murray (1985b) reported feeding previously underfed ewes a high plane of nutrition 10 days before parturition increased the volume and yield of colostral constituents (lactose, fat, protein) by about 30% compared with underfed ewes. Hall et al. (1992) found that feeding supplemental protein for the last 21 days of pregnancy increased colostrum production. Therefore, protein supplementation during late pregnancy appears to increase the amount of colostrum available for the neonate. Although the neonate's initial source of nutrients and immunoglobulins are major factors contributing to early lamb survival, research evaluating the effect of protein supplementation on yields of fat, lactose, protein and immunoglobulins in colostrum is minimal. The objectives of this study were 1) to evaluate the effects of feeding three protein levels during late pregnancy on subsequent colostrum characteristics in the ewe, and 2) to determine how protein supplementation affects IgG concentrations in colostrum and maternal and neonatal serum.

Materials and Methods

Animals and Supplementation Treatments

Twenty-six Rambouillet ewes determined by ultrasound to be pregnant with twins and with known breeding dates were selected for this study. Ewes were weighed approximately 4 weeks before parturition and had an average body weight (BW) of 92.1 ± 7.7 kg (mean ± SD). Average body condition 4 weeks before estimated parturition was 3.4 ± 0.4 on a

Table 2. Body weight (BW) changes of ewes and their offspring.

	Treatments[a]			
Item	85%	100%	115%	SE
Ewe BW, kg				
4 weeks before parturition	93.2	89.6	94.3	2.9
24 hours after parturition	81.6	81.1	86.5	2.5
Weight loss	11.6[b]	8.7[c]	7.8[c]	1.2
Lamb BW, kg				
Birth	4.8	4.8	4.9	0.2
24 hours after birth	4.9	4.9	5.0	0.2
90-day adjusted weaning weight	30.2[e]	30.9[e]	33.4[d]	1.7

[a] Treatment: 85% (ewes, n = 9; lambs, n = 18), 100% (ewes, n = 10; lambs, n = 20), and 115% (ewes, n = 7; lambs, n = 13) of their crude protein requirements on a dry matter basis.
[b,c] Row means with different superscripts differ (P = 0.07).
[d,e] Row means with different superscripts tended to differ (P = 0.12).

scale of 0 to 5, with 0 representing an extremely thin animal and 5 representing an overweight animal (Sheep Industry Development Program, 1987).

Ewes were allotted randomly to one of three dietary treatments based on BW. The treatments were: 1) 85% CP (n = 9 ewes), 2) 100% CP (n = 10 ewes), and 3) 115% CP (n = 7 ewes) of their CP requirements (NRC, 1985). Corn was fed to make the diets isocaloric. Chemical composition of the dietary supplements and percentage of dietary ingredients per treatment group are shown in Table 1.

Ewes were penned individually (1.22 x 1.52 m) on expanded metal flooring and were fed an initial diet of chopped grass hay (9.85% CP) at 2.0% of BW at 0630 hour for 6-15 days (depending on date of parturition) to allow adaptation to diet and pens. Ewes were then separated into two blocks according to estimated date of parturition. Both blocks were distributed across treatments, with Block 1 consisting of 18 ewes and Block 2 consisting of 8 ewes. The feeding phase (dietary treatment phase) of the experiment began 23 ± 2.9 days (Block 1; mean ± SD) and 26 ± 1.6 days (Block 2; mean ± SD) before parturition. Ewes were allowed ad libitum access to water and trace mineralized salt (Cargill, Minneapolis, MN; guaranteed analysis: NaCl, 96 to 98%; ZN, .30%; Mn, .20%; Fe, .20%; Cu, .04%; Co, .002%; I, .002%). Daily feed intake was determined at 0600 by weighing any refusals. Refusals were seldom and consisted mostly of fines from the chopped hay. The protocol for this experiment was approved by the Animal Care Committee of the University of Nevada according to guidelines provided by the Consortium (1988).

Ewes were given 30 minutes after the first signs of parturition [i.e., water bag, sign of lamb(s), etc.] to give birth naturally. If after 30 minutes the lambs had yet to be born, the lambs were pulled manually. Ewes were allowed to mother their lambs and before lambs suckled, both lambs were muzzled with JorVet Muzzles (snout size 13.34 cm or 15.24 cm, Jorgensen Labo-

Table 3. Colostrum weight (g) and volume (mL) from ewes milked every 6 hours for a period of 24 hours.

	Colostrum weight (g)				Colostrum volume (mL)			
	Treatments[a]				Treatments[a]			
Hour[b]	85%	100%	115%	SE	85%	100%	115%	SE
0	1017[de]	954[de]	1414[ce]	182	973[de]	909[de]	1338[ce]	180
6	727[f]	626[f]	676[f]	75	703[f]	603[f]	654[f]	73
12	679[f]	557[f]	540[f]	59	666[f]	543[f]	524[f]	58
18	535[f]	589[f]	1014[g]	220	522[f]	577[f]	993[e]	219
24	763[f]	587[f]	639[f]	83	741[ef]	571[f]	627[f]	82
SE	105	100	119		104	99	118	

[a] Treatment: 85% (n = 9), 100% (n = 10), and 115% (n = 7) of their crude protein requirements on a dry matter basis.
[b] Colostrum collection began immediately following parturition (hour 0) and continued every 6 hours for a period of 24 hours. Colostrum was collected by oxytocin-induced machine milking. Lambs were not allowed to suckle during the 24 hour collection period.
[c,d] Row means with different superscripts differ for colostrum weight (P = 0.06) and volume (P = 0.09).
[e,f,g] Column means with different superscripts differ (P < 0.10).

Table 4. Average percentage of colostrum fat, protein, lactose and solids non-fat and total accumulation of colostrum constituents in ewes receiving three levels of crude protein supplementation.

	Treatments[a]			
Item	85%	100%	115%	SE
Fat, %	7.1	7.7	7.7	1.3
Protein, %	6.5	7.7	8.4	1.4
Lactose, %	3.7	3.7	3.9	0.3
Solids non-fat, %	8.5	9.6	9.0	1.0
Total fat/milking, g[b]	53.8	53.6	54.2	13.0
Total protein/milking, g[b]	50.1	60.1	64.7	23.0
Total solids non-fat/ milking, g[b]	57.8	57.2	50.4	13.2

[a] Treatments: 85% (n = 9), 100% (n = 10), and 115% (n = 7) of their crude protein requirements on a dry matter basis.
[b] Percentage of constituent x grams of colostrum per 6 hour milking.

ratories, Inc., Loveland, CO).

Collection of Ewe Blood and Colostrum Samples
Blood samples (5 mL) were obtained from all ewes via jugular venipuncture every 6 hours (based on time of parturition) for a period of 24 hours, beginning within 1 hour after parturition. Blood samples were stored at 4°C for 24 hours, then serum was separated by centrifugation (1200 x g at 4°C) and stored at -20°C until analyzed for hormone concentrations.

Ewes were milked every 6 hours for 24 hours immediately after collection of blood samples with an Alfa Laval Agri Sheep Milker (Alfa Laval Agri Inc., Kansas City, MO). Ewes' teats were dipped in Nolvasan Solution (Fort Dodge Laboratories, Inc., Fort Dodge, IA) and dried with paper towels before attachment of the teat cup to reduce the risk of infection. Twenty IU of oxytocin (Sanofi Animal Health Company, Overland Park, KS) were administered to each ewe intramuscularly to induce milk letdown. Approximately 2 minutes after injection of oxytocin, the teat cups were placed on the teats and milking continued until colostrum output began to decrease (pulsator set at 120/180 pulse per minute at 50:50 ratio). Any remaining colostrum was hand-stripped.

Colostrum collected at each milking was weighed (g) and measured for volume (mL). Subsamples were collected at each milking and for IgG analysis. Another subsample was collected and analyzed for milk composition (fat, protein, lactose, and solids non-fat).

Lamb Blood Collection and Feeding
After birth, lambs were weighed, sexed, ear-tagged, and their navels treated with iodine. Blood samples (3 mL) were obtained from all lambs via jugular venipuncture within 30 minutes after parturition and again 1 hour later. Additional samples were collected every 3 hours for a period of 24 hours. Samples were processed as described for ewes.

Immediately after collection of blood samples, lambs were tube-fed with 30g/kg of BW of their dam's colostrum at 3 hour interval during the first 12 hours and at 18 hours (Bobb, 1997). Some ewes did not produce enough colostrum for both of their offspring to be fed the appropriate amount of colostrum. Therefore, one lamb was given a substitute of colostrum from any high producing ewe. Three lambs from the 85% group, seven lambs from the 100% group, and two lambs from the 115% group were removed due to consumption of colostrum other than their dam. One lamb died during parturition in the 115% group.

After the 24-hour period, muzzles were removed from lambs, and ewes and lambs were weighed. After nursing, both the ewe and her lambs were placed in feedlot pens and group fed. All ewes received the same diet, which consisted of ad libitum access to alfalfa hay the first month of lactation. Subsequently, ewes and their offspring were maintained on pasture as one group until lambs were weaned.

Laboratory Analyses
Diet samples were analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF) content (Goering and Van Soest, 1970). Acid detergent insoluble nitrogen (ADIN) was determined as the nitrogen fraction of the ADF residue (Goering and Van Soest, 1970). Crude protein content of diet samples was

Table 6. Total lactose (g) in colostrum obtained from ewes at 6 hour intervals following parturition (hour = 0).

	Treatments[a]			
Hour	85%	100%	115%	SE
0	28.4[c]	25.4[c]	37.2[b]	4.3
12	25.4[b]	19.1[c]	18.4[c]	6.7
18	21.7	25.6	22.1	6.2
24	31.6	26.0	23.7	4.3

[a] Treatment: 85% (n = 9), 100% (n = 10), and 115% (n = 7) of their crude protein requirements on a dry matter basis.
[b,c] Row means with different superscripts differ (P < 0.10).

determined as Kjeldahl N (AOAC, 1984).

Colostrum samples were sent to the Dairy Herd Improvement Association (DHIA) in Fresno, CA for determination of colostrum composition (fat, protein, lactose, and solids non-fat). Due to transportation problems, over half of the ewe samples collected at hour 6 after parturition had soured and could not be analyzed. Samples collected at hour 6 were excluded from the statistical analysis for percentage of fat, protein, lactose and solids non-fat.

Serum and colostrum IgG concentrations were quantified by radioimmunoassay (RIA) as described by Richards (1998). The intra- and interassay coefficients of variation (CV) were 8.4% and 17%, respectively.

Statistical Analyses
Animal weights, serum and colostrum IgG concentrations, and colostrum components were analyzed by a split-plot analysis of variance using effect of dietary treatment for the main plot and time of sampling for the subplot in a completely randomized block design. The effect of diet and block was tested utilizing the GLM procedure of SAS (1988). Animal within dietary treatment by block was used as the error term. When significant treatment x time interactions ($P < 0.10$) were detected, effects of treatment were examined within sampling time. The least significant difference option of SAS (1988) was used to determine mean differences when a significant F-test ($P < 0.10$) was detected. Lambs that received colostrum from a dam other than their own were excluded from IgG analysis. The correlation procedures of SAS (1988) were used to determine the relationship between serum (ewe and lamb) and colostrum IgG concentrations for each sampling time.

Results and Discussion

Ewe and Lamb Performance
Ewe BW was influenced by treatment x day interaction ($P = 0.06$) in relation to protein intake (Table 2); therefore, BW was examined within day. Ewe BW did not differ among treatments 4 weeks before parturition or 24 hours following parturition (Table 2). However, BW loss was greater ($P = 0.07$) in ewes receiving 85% CP than in ewes receiving either 100% or 115% CP. Similarly, Roeder et al. (1996) also found that ewes fed a diet restricted in CP had a greater weight loss at lambing than ewes fed an increased plane of CP (blood meal-feather meal mix diet). Likewise, Hatfield et al. (1995) found ewes receiving a high CP diet gained more BW from 30 days prepartum to 4 days postpartum.

Similar to previous reports by McFaden et al. (1996), lamb weight immediately following parturition and 24 hours after parturition did not differ ($P = 0.28$) among treatments (Table 2). In contrast, Ripley et al. (1987) reported that birth weights were heavier in lambs born to ewes receiving high protein supplements, however, ewes were supplemented beginning mid-pregnancy. Lambs whose dams received 115% CP tended ($P = 0.12$) to have heavier 90-day adjusted weaning weights than lambs produced by ewes receiving 85% or 100% CP. Beetson (1984) reported a 13% increase in weaning weights of lambs from ewes fed a high level (HL) of supplementation over ewes fed a low level (LL) of supplementation. In addition, this author also found lambs born to HL ewes were 5% heavier at birth than the LL lambs. Mellor (1983) reported that the growth rate of lambs up to weaning was positively correlated with the plane of nutrition experienced by the ewes during late pregnancy. Therefore, lambs from ewes that received a higher plane of nutrition 3 to 4 weeks before parturition have the potential to attain heavier weaning weights.

Colostrum Characteristics
A treatment x time of milking interaction was observed for both colostrum weight (g) and colostrum volume (mL; $P < 0.10$; Table 3); therefore, individual milking times were examined. Prepartum colostrum (hour 0) weight ($P = 0.06$) and volume ($P = 0.09$) were greater in ewes receiving 115% CP than ewes receiving either 100% or 85% CP (Table 3). No differ-

Table 5. Effect of time after lambing on percentage of colostrum fat, protein, lactose, and solids non-fat and total accumulation of colostrum constituents in ewes across treatments.

Hour	Fat	Protein	Lactose	Solids non-fat	Total fat	Total protein	Total solids non-fat
	%	%	%	%	g	g	g
0	8.9^{b}	9.1^{b}	2.5^{c}	3.7^{c}	95.2^{b}	115.3^{b}	39.7^{c}
12	$7.4^{b,c}$	$7.8^{b,c}$	$3.7^{b,c}$	10.9^{b}	45.9^{c}	46.0^{c}	64.0^{b}
18	6.8^{c}	$6.5^{c,d}$	4.2^{b}	10.9^{b}	39.4^{c}	38.6^{c}	62.4^{b}
24	8.3^{b}	5.2^{d}	4.2^{b}	10.3^{b}	54.5^{c}	33.4^{c}	67.2^{b}
SE	0.6	0.7	0.2	0.8	8.4	13.1	7.0

[a]Percentage of constituent x grams of colostrum per 6 hour milking.
[b,c,d]Column values with different superscript differ ($P \leq .001$).

Table 7. **Concentrations of immunoglobulin G (IgG) in ewe serum and colostrum.**

Item	Treatments[a] 85%	100%	115%	SE
Serum IgG, mg/mL	11.9	10.8	11.8	0.8
Colostrum IgG concentration, mg/mL	17.8[d]	20.8[c,d]	24.0[c]	2.1
Total Colostrum IgG/ 6 hour milking, g[b]	16.4	13.0	15.2	2.2

[a] Treatments: 85% (n = 9), 100% (n = 10), and 115% (n = 7) of their crude protein requirements on a dry matter basis.

[b] Total IgG = colostrum IgG concentration x colostrum volume. Mean value represents the average for the 6-hour sampling period.

[c,d] Row means having different superscripts differ (P = 0.10).

ences were detected between 100% and 85% groups. Neither colostrum weight or colostrum volume was affected (P > 0.10) by dietary treatment at hours 6 or 12. At hour 18, ewes consuming 115% CP produced more colostrum than ewes consuming either 100% or 85% CP. No effects of treatment (P > 0.10) were found for either colostrum weight nor colostrum volume at hour 24. Prepartum colostrum accumulation within each treatment was greater (P < 0.10) than yields determined at 6-hour collections postpartum. Total colostrum produced after parturition (hour 6 through hour 24) did not differ (P > 0.10) among treatments (2704, 2359, and 2870 ± 377 g and 2635, 2294 and 2798 ± 331 mL for ewes receiving 85%, 100% and 115% of CP requirements, respectively). Treatment had no effect on colostrum density overall mean (1.03 ± .004 g/mL). Amounts of colostrum produced (g and mL) in our study are much greater than those reported by Mellor and Murray (1985a, b) in Scottish Blackface ewes receiving a high plane of nutrition following parturition and by Shubber et al. (1979) in mature Greyface ewes producing triplets. Differences among studies may reflect, at least in part, breed differences.

Robinson et al. (1979) found that increased CP intake increased colostrum/milk yield in ewes. Cowan et al. (1981) suggested increased colostrum/milk production resulting from additional protein intake may be due to an increase in amounts of essential amino acids available for absorption from the small intestine. Furthermore, Mellor and Murray (1981) reported that ewes consuming a high plane of nutrition experienced not only a markedly increased term weight of udder tissue, but their total yield of colostrum was 43% greater than ewes on a low plane of nutrition. Although beyond the scope of our study, it is possible that by increasing CP intake udder development was euhanced, thereby, increasing the ability of the mammary gland's capacity to produce colostrum.

Use of a Milking Machine for Colostrum Determination

Normally, colostrum is produced for 18 to 24 hours after parturition (Mellor and Murray, 1986). It is possible, however that the use of a milking machine could cause a shift in lactogenesis from colostrum production to milk production before this 18 to 24 hour period. Colostrum samples collected in the present study exhibited a visual color change from hours 0 to 24, beginning at approximately hour 12. Directly following parturition the samples were bright yellow. This color decreased in intensity with time and was an off-white color by 24 hours after parturition. Colostrum consistency also changed over time. At hour 0 and hour 6 the colostrum was extremely thick and creamy, at hour 12 the consistency had changed to a thick yet pourable liquid, and by hours 18 and 24 the samples were similar to water in consistency. The use of a milking machine may alter the profile of lactogenesis (colostrum vs. milk production) with reference to time (12 hours vs. 24 hours).

Colostrum Constituents

No treatment x time of milking interactions (P > 0.10) were detected for percentage of fat, protein, lactose and solids non-fat; therefore, overall means are reported (Table 4). Average total percentage of fat, protein, lactose and solids non-fat in colostrum did not differ (P > 0.10) among treatments (Table 4). Likewise, Roeder et al. (1996) did not detect differences in colostrum constituents in ewes fed a restricted CP diet or supplemented with soybean meal during late lactation. Our values for percentage of fat, protein and lactose are similar to values reported by Kremer et al. (1996) but lower than those reported by Roeder et al. (1996). Differences among studies may be due to time when samples were collected after parturition and/or if a small sample was collected from each teat or the ewe was milked out and a subsample obtained. Total amounts (% of constituent x g of colostrum) of fat, protein and solids non-fat were not affected (P > 0.10) by supplementation (treatment x time of milking interactions, P > 0.10; Table 4). Because

Table 8. Effect of time after lambing on immunoglobulin G (IgG) concentrations in colostrum and ewe serum across treatments.

Hour	Colostrum IgG, mg/mL	Total colostrum IgG, g	Serum IgG, mg/mL
0 (parturition)	42.6[a]	44.0[a]	12.9[a]
6	27.1[b]	17.6[b]	10.6[b]
12	14.3[c]	8.0[c]	11.6[b]
18	5.6[d]	3.3[cd]	11.5[b]
24	3.8[d]	2.2[d]	10.8[b]
SE	1.2	2.2	0.5

[a,b,c] Column values with different superscripts differ (P < 0.10).

no treatment x time of milking interactions were detected (P > 0.15) for percentages of fat, protein, lactose, and solids non-fat, and total accumulation of fat, protein, and solids non-fat, values were pooled across treatments and are shown in Table 5. The percentage of fat in colostrum was greater (P < 0.05) at hour 0 than at hours 12 and18. However, total colostrum fat accumulation was greatest (P < 0.05) at hour 0 and then decreased but did not differ (P > 0.10) among collection times after parturition. Colostrum protein percentage decreased (P <0.05) over the sampling period. Total colostrum protein accumulation was the greatest at hour 0 (P < 0.05) then decreased by over half by hour 12; sampling times did not differ (P > 0.10) among hours 12, 18 and 24. During the prepartum period, IgG is transported from the blood into the mammary gland and the higher protein concentration is mainly from accumulation of IgG during the prepartum period (Larson et al., 1980), therefore, elevated colostrum protein would be expected. As observed in our study, concentration of IgG and subsequently protein content have been shown to decrease with each successive milking (Oyeniyi and Hunter, 1978; Larson et al., 1980). The percentage of lactose was lowest (P < 0.05) at parturition after which values increased through hour 18. Colostrum solids non-fat percentage and accumulation increased (P < 0.05) from hour 0 to hour 12, after which values did not differ (P > 0.10). Because several of the colostrum constituents changed at hour 12 and are similar to values found in milk (protein, lactose, solids non-fat; Sakul and Boylan, 1992), these data would support the observation that use of the milking machine may have altered the profile of lactogenesis with reference to time (12 hours vs 24 hours).

Total lactose in colostrum was affected by a treatment x time of milking interaction (P = 0.09, Table 6). Prepartum lactose accumulation was greater in ewes consuming 115% CP than ewes consuming either 100% or 85% CP. This reflects an increase (P < 0.05) in colostrum yield rather than an increase (P > 0.10) in the percentage of lactose in colostrum. Yield of lactose at hour 12 was greater (P < 0.10) for ewes in the 85% group than ewes in the 100% or 115% groups. No differences (P > 0.30) were detected in response to CP intake at hours 18 and 24. Cowan et al. (1981) reported lactose concentrations were unaltered in ewes receiving either a high plane or low plane protein diet. However, Hatfield et al. (1995) found ewes that were fed 14.9% CP 30 days prepartum had a greater percentage of lactose in their colostrum than ewes fed 11.3% CP.

Serum and Colostrum IgG Concentrations

No treatment x time of sampling interactions (P > 0.20) were detected for IgG concentrations in ewe serum or colostrum (Table 7). Concentrations of IgG in ewe serum were not affected (P = 0.40) by treatment. However, increased CP consumption from 85% to 115% resulted in a trend (P = 0.11) toward increased IgG concentrations in colostrum. Blecha et al. (1981) also reported colostrum IgG concentrations to be greater in heifers receiving a high protein diet than a low protein diet during the last 100 days of gestation. Total IgG in colostrum (IgG mg/ml x colostrum volume) was not affected (P =0.70) by treatment. IgG available in colostrum (g) and IgG concentrations (mg/mL) were different between sampling times (P = 0.0001). Because no treatment by time interactions (P = 0.40) were detected, IgG values were pooled across treatments and are shown in Table 8. Colostrum IgG concentrations and total grams produced were greatest (P < 0.10) at parturition and decreased through hour 24. This decline leads to the suggestion that the mammary gland loses its ability to absorb IgG from the blood 18 to 24 hours after parturition. In addition, the amount of IgG available for the lamb is drastically decreased 12 hours after the first feeding and lambs that fail to feed during this period may not obtain sufficient intake of IgG. IgG concentrations in ewe serum were highest (P < 0.10) at parturition, then slightly declined but remained similar among sampling times 6 to 24 hours after parturition.

A treatment x time of sampling interaction was detected (P < 0.05) for concentrations of IgG in lamb serum (Table 9). Serum IgG values at hour 0 are not shown in Table 8 because several lambs across treatments had non-detectable levels of

Table 9. Concentrations of serum immunoglobulin G (IgG;mg/mL) in lambs[a] produced by ewes receiving three levels of crude protein.

	IgG			
	Maternal treatments[b]			
Hours after birth	85%	100%	115%	SE
	(n=15)	(n=13)	(n=11)	
1	4.2	3.6	1.6	2.0
3	4.7	5.6	4.1	1.9
6	16.4	16.6	16.8	1.9
9	16.1	18.9	17.7	2.0
12	28.0[d]	22.0[e]	32.7[c]	2.0
15	25.6	28.1	28.0	2.1
18	17.8[d]	21.7[c]	20.4[c,d]	1.9
21	24.4	26.0	24.1	2.3
24	21.9	25.0	25.1	2.0

[a] Lambs were fed their dam's colostrum at 30 g/kg of body weight at hours 0 (birth), 3, 6, 9, 12 and 18. Blood samples were collected before feeding.
[b] Treatment: the lambs' dams received 85%, 100% or 115% of their crude protein requirements on a dry matter basis.
[c,d,e] Row means with different superscripts differ ($P < 0.05$).

IgG before receiving colostrum. However, 21 of the lambs had detectable amounts (range 1.2 to 13.3 mg/mL) of IgG at hour 0 even though they were restricted from feeding. Interestingly, those lambs which had detectable amounts of IgG by hour 0 had considerably lower values at hour 1 (range 0.5 to 5 mg/mL). According to Reneau et al. (1973) and Waelchli et al. (1994), it is not uncommon to detect small amounts of IgG (0.07 to 3.0 mg/mL) in newborn lambs before they receive colostrum. In some of the lambs in our study, IgG values were three to four times greater than those previously reported. The reason for this is unknown. Following colostrum intake, concentration of IgG in lamb serum had increased over time, but no treatment effects ($P > 0.10$) were observed until hour 12. At that time, lambs from ewes in the 115% CP group had greater ($P = 0.05$) serum concentration of IgG than lambs from ewes in either 100% or 85% CP groups; lambs from the 85% CP group had more IgG than lambs from the 100% CP group. No differences in serum IgG concentrations were detected at hour 15; at hour 18, serum IgG concentrations were greater ($P = 0.05$) in lambs produced by dams fed 100% CP than by dams fed 85% CP. Lambs from the 115% CP treatment had similar IgG concentrations to both the 100% and 85% CP groups. Similar IgG values have been reported by others (Halliday, 1978; Cabello and Levieux, 1981).

Correlation of IgG in Colostrum and Ewe/Lamb Serum

Serum IgG (mg/mL) in ewes was positively correlated with IgG in colostrum at hour 0 ($r = 0.55$, $P = 0.002$), no relationship was observed after parturition ($r = -0.17, -0.08, 0.11$ and 0.05 for hours 6, 12, 18 and 24, $P > 0.43$). No significant correlations ($P > 0.20$) were detected between colostrum and lamb serum IgG concentrations for any sampling times ($r = 0.22, 0.28, 0.07$ and 0.22 for hours 6, 12, 18 and 24).

Conclusions

CP supplementation that meets or exceeds requirements in pregnant sheep appears to be beneficial during the last 3 to 4 weeks of gestation when nutrient demands are high. Crude protein supplementation above maintenance requirements allowed for less weight loss in dams bearing twins. Additionally, lambs from ewes receiving CP in excess of maintenance requirements tended to have heavier 90-day adjusted weaning weights. It is also suggested that the accumulation of colostrum prepartum and IgG concentrations in colostrum the first 24 hours after parturition may be improved by supplementing with CP. By increasing ingestion of colostrum in suckling lambs the lamb's chance of acquiring sufficient immunoglobulins and initial nutrients needed for early survival may be enhanced. Thus, the implementation of a short-term CP supplementation program may provide a more beneficial method of enhancing the ewe's nutritional status during late gestation and lactation, and also improve lamb performance.

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The Economics of Suckler Kids on Dairy Goat Farms

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Summary

This study examines the economics of combined milk and meat production as an alternative to the current specialized goat milk production in Norway. The reasons for the study are 1) to increase goat farm profitability, 2) to improve the annual distribution pattern of goat milk supplies, and 3) to reduce negative publicity on farmers who dispose of surplus goat kids just after birth. A linear programming model was worked out, maximizing farm profit of a goat farm with kidding in February, December and April/May, including raising or disposing of the kids for each kidding date. The most profitable management practice would be to change the time of kidding from February to late April or May, combined with suckling during the day until August. The kids are to be slaughtered in August to utilize the summer grazing period and market before start of the lamb slaughter season. While the kids are being suckled, the does are milked once a day and after weaning twice a day, thereby increasing milk supplies during autumn and winter when milk prices are higher. The model was designed with the actual subsidies for Norwegian goat farming, however a discussion of how the Norwegian agricultural policy, as well as the natural conditions which contribute to the results, has been incorporated to increase the relevance of the study to other countries.

Key words: economic analysis, goats, meat, milk, farm management

Introduction

Goat farming in Norway is facing an uncertain future due to a changing market. Milk has been the major product of the industry and most of it is delivered to dairies and used for production of brown Norwegian goat cheese. However, due to decreased sale of the traditional brown cheese, a goat milk quota system has been in effect since the mid-eighties. There is demand for Frozen Curd and the newly developed brand cheese "Snofrisk" (i.e. Snow-fresh), has been successfully marketed on the local market as well as in the US. "Snofrisk" is a white spreadable cheese which can be stored for only three months. Manufacturing of the cheese requires an even supply of fresh milk throughout the year in order to ensure stable production.

The Norwegian Milk Marketing Board has increased the price of goat milk substantially for November, December and January in order to improve annual distribution of milk. However, under the present system, most of the kidding takes place in February and stable milk deliveries are difficult to achieve. After kidding, the goats are barnfed until the start of grazing season in May or June. Grazing on the natural pastures ends in September or October. The goats are then milked for a period of 1 -3 months and dried off 2 - 3 months before parturition. The result of the system is peak deliveries of milk from April to September and a shortage during mid winter.

Goat meat traditionally has a lower price than other meats on the Norwegian market and has mostly been used in different mixed meat products. Surplus kids are culled just after birth without any attempt being made to utilize them for meat production. Killing of surplus kids has been criticized by animal rights advocates. Today, increased demand from hotels and large households, especially in August, before the slaughter season for lambs, may provide market opportunities for profitable meat production of medium sized goat kids. While on pasture the kids may partly nurse the does and thus reduce the amount of milk marketed in the low price period, saving the larger amount

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Table 1. Production and farm profit in 1997 with 2,600 or 2,860 h of family labor input on a Norwegian goat farm with a milk quota of 40,000 liters, kidding in February with disposal of surplus kids compared to raising the kids.

			Farm profit 1997, US $	
Activities	Utilized land, hectares	Dairy goats	Basic 2,600 h	+ 10% labor input
Disposal of surplus kids	4.9	77.6	14,202	15,377
Sale of kids, $ 3.93 per kg				
Three weeks, suckler	5.1	80.8	14,638	16,344
Six weeks, milk replacer	4.9	77.6	13,461	15,355
Six weeks, suckler	5.6	87.7	13,039	16,743
August, milk replacer	5.6	77.6	15,405	17,652
August, suckler	6.3	87.7	14,852	18,556
Sale of kids, $ 5.52 per kg				
Three weeks, suckler	5.1	80.8	15,151	16,858
Six weeks, milk replacer	4.9	77.6	14,237	16,126
Six weeks, suckler	5.6	87.7	13,909	17,613
August, milk replacer	5.6	77.6	17,485	19,732
August, suckler	6.3	87.7	17,202	20,905

for the winter with a higher price. Use of suckler kids might, however, require a change in kidding period.

The purpose of the study is to examine the economics of goat production with the present practice of disposing of surplus kids just after birth compared to a system with different kidding seasons and the use of suckler kids for meat production.

Materials and Methods

A linear programming (LP) model was worked out using the spreadsheet Excel. For a general overview of the comprehensive literature on LP, see, for instance, Hadley (1974) or consult Barnard and Nix (1979) on how LP can be applied in farm management. The LP-model calculates the maximum farm profit of goat farming, i.e. total farm output less the sum of variable and fixed costs (Ministry of Agriculture, Fisheries and Food, 1983). Based on five farm records for 1995 and 1996 from Western Norway (Norwegian Agricultural Economics Research Institute, 1996; 1997a), the LP-model was designed to represent the approximate average result of dairy goat farms in 1997. The farms had an average kidding date in February followed by disposal of surplus kids. However, the LP-model was also calculated for kidding in December and in April/May, including raising or disposing of the kids for each kidding date. The result of the calculations were transformed to US $ using the average exchange rate for 1997, i.e. $1 = 7.08 Norwegian kroner.

The LP-model consists of 23 activities, 10 on feeding (five for roughage and five for concentrate) and eight on animal husbandry. Labor can be hired in a separate activity and rural area support is incorporated in the model by three transferring activities. The fixed costs are subtracted in a separate activity, forced into the solution with one unit.

The size of the activities is determined within 22 constraints. The most important constraints are labor input during the summer season and total family labor input which are linked with parameters for labor requirement for crops and for animal husbandry activities, respectively. The average size of the recorded farms (7.5 hectares) was also used for the LP-model. On goat farms, most of the area is used as meadow and the only constraints are the need to establish new grassland on at least 10 percent of the area and the need to dispose of animal manure on plowed land. Natural conditions of the area determine the length of the grazing period (22 May - 21 October) and yields per hectare which are linked with parameters for feeding requirements indoors and on pasture.

The parameters for feed requirement of does with varying periods of kidding are based on studies of milk curves and actual feeding plans, detailed on a weekly basis. There is a constraint on total energy requirement during the barn feeding period, supplied either by roughage or concentrate feed. During this period, the goats are fed grass silage ad libitum and a maximum constraint on the amount of concentrate is applied. For milking does there are also two minimum amounts of concentrate required, before and after kidding, as well as a minimum concentrate requirement for the grazing period. For December and February kidding, standard levels of concentrates are employed (1.0 kg/day/doe from kidding to start of grazing, 0.4 kg during the grazing period, 0.6 kg during barnfeeding in late lactation, and 0.3 kg of concentrates during the dry period of three months). For May kidders, supplemental feeding differed from that of December and February kidders in the first period (0.6 kg/day/doe) and from September until end of lactation (0.9 kg/day/doe). The high levels of concentrates used during the last part of lactation for May kidders should sustain milk production (Eik et al., 1998) and prevent the normal drop in yield due to low quality of pastures in the fall (Ronningen,

Table 2. Production and farm profit in 1997 with 2,600 or 2,860 h of family labor input on a Norwegian goat farm with a milk quota of 40,000 liters, kidding April 30 to May 15 with disposal of surplus kids compared to raising the kids.

Activities	Utilized land, hectares	Dairy goats	Farm profit 1997, US $ Basic 2,600 h	+ 10% labor input
Disposal of surplus kids	5.5	77.6	17,669	18,844
Sale of kids, $ 3.93 per kg				
Three weeks, sucklers (30 April)	5.7	80.9	18,183	19,953
August, 3 months (30 April)	6.9	97.4	19,531	23,234
August, 2.5 months (14 May)	6.6	93.8	21,183	24,886
Sale of kids, $ 5.52 per kg				
Three weeks, sucklers (30 April)	5.7	80.9	18,697	20,467
August, 3 months (30 April)	6.9	97.4	20,976	24,679
August, 2.5 months (14 May)	6.6	93.8	22,392	26,095

1964; Ronningen & Gjedrem, 1996; Steine, 1975 and Heldal, 1978). Goats kidding in spring also have to be fed supplements with grass in the grazing period, modeled as a minimum requirement.

Kids born in February or December and slaughtered at six weeks of age (5 kg) will either nurse 37 liters of milk or receive milk replacer the last five weeks. Total use of milk replacer is 2 kg per kg slaughter weight (Vinje, pers. com.) at a price of $1.69 per kg. Kids born in April or May will nurse until August 1 (65 and 55 liters, respectively) and do not need concentrate during this period. There is a (minimum) requirement of concentrates for kids older than six weeks unless they are born in April/May and slaughtered in August.

The governmental support for preservation of the countryside is incorporated in the model and amounts to $ 568 per hectare for the first 10 hectares of agricultural land and $ 273 for the next 15 hectares. For each animal grazing at least eight weeks on open range pastures, 0.032 hectares of land is added to the basis. Due to their browsing characteristics, goats are efficient in reducing amounts of shrubs in the pasture and keeping the landscape open whenever desirable.

The LP-model milk quota constraint (40,000 liters) and the yield (515 liters per milking goat) are approximately the same as the average of the recorded farms. Reduction in milk deliveries due to suckling are based on experiments on Norwegian goats (Eik et al., 1992; Eik et al., 1998; Eik et al., unpublished data). The following milk price pattern has been used: $ 0.68 per liter (weeks 5-39), $ 0.71 per liter (weeks 40-43), and $ 1.07 per liter (weeks 44-4). Price variation is determined by the Norwegian Milk Marketing Board which has increased the price of goat milk substantially for November, December and January in order to achieve more stable deliveries.

The price per kg of goat meat has been set to $ 3.93 by the farmers cooperative marketing board, Norwegian Meat, including rural support ($ 0.57 per kg in the area). By contract deliveries, a price of $ 5.52 per kg is obtained for carcasses of good quality and convenient size. As for different farm inputs, the prices were set as for the year 1997 based on farm records (Norwegian Agricultural Economics Research Institute, 1996; 1997a) and the Handbook of Farm Planning (Norwegian Agricultural Economics Research Institute, 1997b)[1].

Results

Kidding in February

The 1997 basic solution of the LP-model with disposing of surplus kids resulted in a farm profit of $ 14,202 (Table 1). The family labor input was set at 2,600 h and 435 h was hired; somewhat less than in the farm account material (568 h in 1996). If 10% higher family labor input is assumed (2,860 h), the farm profit increases to $15,377. Not all the land is necessary for the goats, as recorded farms had a few sheep and some fallow agricultural land to make up for that, but these activities are exogenous to the LP-model.

The optimum herd size was 77.6 milking does while the farm accounts showed an average of 78.2. It will, in general, be profitable to exploit the whole milk quota and unprofitable to produce more milk than the quota. The alternatives, with 10% higher labor input, thus yielded the same solution, except that the input of hired labor was reduced when the family worked more. However, two requirements limit the reduction of hired labor. First, the governmental subsidy for substitute workers during holidays is paid out only for hired labor. Second, the labor required depends on the season. It may sometimes be necessary to hire labor in the summer in spite of excess family labor in the winter.

Raising the kids for three weeks can be slightly advantageous compared to disposing of them just after birth, even with the normal price of meat (Table 1). Since the kids will nurse colostrum for the first five days, not much extra milk would be required for an additional 16 days. Slaughtering the kids at six weeks is unprofitable even with the highest meat price. The solution requires considerably more goat milk or milk replacer. With the use of goat milk, 10 more goats are needed to fill the quota, and the building capacity might have to be increased. With milk replacer, extra building capacity is not needed. Selling three week old

Table 3. Production and farm profit in 1997 with 2,600 or 2,860 h of family labor input on a Norwegian goat farm with a milk quota of 40,000 liters, kidding around December 17 with disposal of surplus kids compared to raising the kids.

Activities	Utilized land, hectares	Dairy goats	Farm profit 1997, US $ Basic 2,600 h	+ 10% labor input
Disposal of surplus kids	4.9 - 5.8	77.6	16,134	17,134
Sale of kids, $ 3.93 per kg				
Three weeks, suckler	5.0 - 5.4	80.8	15,966	17,715
Six weeks, milk replacer	4.9 - 5.8	77.6	15,300	17,112
August, milk replacer	6.2	77.6	16,044	18,947
Sale of kids, $ 5.52 per kg				
Three weeks, sucklers	5.0 - 5.4	80.8	16,480	18,228
Six weeks, milk replacer	4.9 - 5.8	77.6	16,075	17,888
August, milk replacer	6.2	77.6	18,347	21,250

kids for the normal price is better than selling six weeks old kids for the higher price.

The best result was obtained when the kids were slaughtered in August (carcass weight 13.5 kg). A price of more than $ 7 per kg is needed for six week old kids to be advantageous compared to kids sold for $ 3.93 at the end of August. One reason for this result is the use of inexpensive range pasture for the kids, as well as support for preserving the countryside for animals grazing more than eight weeks on open ranges. However, building capacity still may have to be increased with suckler goat kids as more goats are needed to fill the milk quota.

Kidding in April or May

If the goat farmer wants to take advantage of the higher milk price in the winter months, kidding cannot occur in February. One alternative would be to move kidding to the spring. Calculations have been carried out with kidding on April 30th and based on either disposing of surplus kids, raising them for three weeks, or until the first of August. Instead of six week old kids, an alternative using 2.5 months old kids was worked out. These kids are born in the middle of May and slaughtered in early August with most of the suckling occurring on pasture. The results of kidding in April or May are shown in Table 2.

Kidding at the end of April with disposal of surplus kids yielded a considerably higher farm profit than kidding in February. Selling three week old kids is profitable even with the normal meat price of $ 3.93 per kg. The improved result in April occurs because a larger share of the milk production takes place in the period from November to January when the price of milk is about $ 0.39 higher per liter. A further postponement until the middle of May will be slightly more favorable than April because of higher production in the high price period. The uncertainty with spring kidding has been the amount of labor required for managing high yielding goats on pasture. However, experience suggests that managing May kidders on pasture will not be substantially different from managing February kidders.

Kidding in spring with kids slaughtered at 2.5 - 3 months of age performed well and seems most promising. Minimum indoor feeding of kids and milking once a day[2] would reduce labor requirement considerably during the grazing period (Eik et al., 1998). Kids may also be marketed at a favorable time just before the lamb season and may have a desirable size (6.5 - 7.5 kg carcass weight) for restaurants. Due to extensive suckling, considerably more goats are needed to fill the quota (Table 3); however, since the replacement kids are born in the spring and give their first birth during the spring, they do not need to be kept indoors during the winter, thus building capacity can be saved for more milking goats with kidding in spring time.

Farmers have, however, criticized the system, claiming there would be too many animals to manage during the summer. This may be the case in the traditional system if two or three farmers have a common milking facility on the pasture, enabling them to share the work and get or use workers during holidays. Special measures, such as extra roughage feeding of the suckler goats, may have to be introduced on common pastures. Another solution may be to practice suckling solely by some goats and keep them on separate pastures with the kids until weaning. Preliminary results from experiments on such a management system are promising (Eik et al., personal communication, 1998); however, the effect on the distribution of milk supplies remains to be examined.

Kidding in December or earlier

By moving kidding to December a considerable increase in milk production in December and especially January is achieved. December kidding is clearly more profitable than kidding in February (Table 3). However, it seems that kidding in December is not as profitable as kidding in April or May as the goats will have their dry period in November. Like February, kidding in December seems most profitable with disposing of surplus kids just after birth or feeding them until three weeks of age if there is excess labor available. Raising the kids for six weeks (milk replacer) is only profitable when there are high meat prices and excess family labor. The kids may become too large for the highest price when born in December, however selling for the normal price in August seems profitable if surplus labor is available.

In order to take full advantage of the higher price of goat milk, kidding should occur in October or earlier, and such alternatives have not been examined. Special measures also have to be introduced to achieve October kidding due to seasonality of mating. However, our experience with December kidding suggests that October kidding is preferred with disposal of surplus kids just after birth or marketing them at three weeks of age. In Norway, extensive work, both at research stations and on farms, has been undertaken on moving the kidding time from February to December (Eik et al., 1997). However, the results are mixed. Some farmers are successful, whereas others may experience a prolonged kidding period and more barren does.

Discussion

Like other farmers, Norwegian goat farmers have to manage and make decisions within the limits of the farm resources and natural conditions of the area as well as the subsidy regime of the country, limiting the applicability of this analysis for other countries. Although goats are efficient in keeping the landscape open, there probably has to be a government payment for preserving the rural landscape if suckler kids are to become profitable. Spring kidding with partial suckling would be favorable for attaining the goal as both goats and kids would be grazing. The results reported here are also due to the limited area of agricultural land and abundant supplies of mountainous pastures which can only be used for a limited part of the year. Under such conditions it seems to be profitable to have kidding occur at a time when pasture is available since suckling is easiest to introduce during the grazing period. Another reason for the results is the quota system for goat milk and the extra payment obtained for goat milk during the winter due to the need for more even supplies. However, quota systems are common in many countries and the results should be of interest in countries with similar systems and conditions.

Kidding occurs on most Norwegian goat farms in February and surplus kids are disposed of shortly afterwards. Since farmers have limited labor available, disposal of surplus kids at birth seems to be a feasible option. The problems with this solution are the limited farm profit due to the milk quota as well as irregular milk supplies. The animal rights advocates also deem the practice unethical and goat farmers dislike the practice themselves. Raising the goat kids may yield additional profit and the farmers may avoid negative publicity.

When goat milk prices are high during the winter, the largest potential for increasing incomes in goat farming is probably to delay the time of kidding until the end of April or just before pasturing in May. Kidding during spring provides the possibility for a suitable kid size for slaughter at the beginning of August, achieved by partial suckling on pasture. It also seems possible to improve the annual distribution pattern of milk supplies as the goats are milked once a day while suckling and twice a day after weaning. However, goats kidding in spring also have to be fed extra during autumn when the quality of the natural pastures deteriorates.

It is also possible to increase incomes by altering the time of kidding to December or earlier, however, disposing of surplus kids is also a likely arrangement in that season. Raising the kids until they are three weeks old might be slightly better in some situations and the industry can avoid some negative publicity. However, the price of meat has to be higher than $ 5.52 per kg and the labor situation flexible in case six week old kids should become a competitive alternative. Such assumptions seem unrealistic. The second best alternative would be to use inexpensive pasture and sell the kids in August.

Conclusions

A system combining milk and meat production from goats kidding in spring is an economically viable alternative to the present system of February kidding and disposal of surplus kids. Introduction of a dual-purpose system on goat farms would also improve annual distribution of the milk supplies and seems clearly beneficial from an animal welfare point of view. Additional research is, however, required to determine how such farming will affect milk quality and whether or not prolonged milking of goats in their final year and reduced length of the dry period can become profitable with spring kidding. Research addressing these issues is in progress.

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Central Test Performance of Rambouillet Rams as a Predictor for Growth and Wool Traits in Feedlot and Range Environments[1]

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Summary

A study was conducted to estimate the relationship between sire's 140-d central test performance and progeny performance. The 9 centrally tested Rambouillet sires were represented by a total of 34 offspring. Regressions of progeny performance (weight gain, body weight, fleece weight, fleece yield, average staple length, and average wool fiber diameter) on sire's central test performance were used to estimate the relationship between central test performance and progeny performance, measured sequentially on the same animals, in feedlot and range environments. The nine sires represented a wide range of performance on central test. The model used for each trait included a fixed effect for type of birth of the lamb (single or multiple), a linear regression for age of the lamb in days at the start of the feeding period, a covariate for sire's performance, a covariate for dam's performance, and random effects for sire and residual error. The covariate for dam's performance was dam's body weight at breeding for gain traits, grease fleece weight of the dam for fleece weight traits and staple length, and average fiber diameter of the dam for fiber diameter traits. The regression coefficients of progeny performance on sire's performance were +.46 ($P < .01$) and -.23 ($P < .1$) for gain, +.46 ($P < .01$) and +.29 ($P < .01$) for body weight, +.34 ($P < .01$) and +.23 ($P < .1$) for clean fleece weight, +.12 ($P > .1$) and .00 ($P > .1$) for fleece yield, +.33 ($P < .05$) and +.09 ($P > .1$) for average staple length, and +.41 ($P < .01$) and +.39 ($P < .01$) for average fiber diameter, in the feedlot and range environments, respectively. There was a strong relationship between sire's performance as measured on 140-d central performance test and progeny performance in a similar environment. When progeny performance was measured on a relatively low nutrition environment, the relationship between central test performance and progeny performance was weakened for growth rate, body weight, fleece weight, fleece yield, and average staple length.

Key words: sheep, wool, central performance test, rambouillet, heritability

Introduction

Central ram performance tests are conducted to identify genetically superior sires for outstanding wool and growth characteristics, and are usually conducted in favorable nutrition environments. High protein (or energy) rations and increased intake generally result in increased growth rate, staple length, fleece weight, and fiber diameter (Schafer, 1992; Bohnert, 1994). Salisbury et al. (1997) found that increasing proportion of escape protein resulted in increases in fiber diameter and staple length in Rambouillet rams. Birrell (1992) showed that increases in forage quality and quantity resulted in an increase in fleece weights and increased average fiber diameter in grazing ewes. Lupton et al. (1992) found that rams' mean fiber diameter decreased after they were removed from favorable nutrition, such as is used for the central performance test, and placed on range. Estimates of a non-significant relationship between central test growth rate of Suffolk rams and their progeny's growth rate (Waldron et al., 1990) have raised questions about the accuracy of central test performance as a predictor of progeny performance. It is not known to what extent performance differences observed among rams on a 140-d central test, with

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Table 1. Central test performance of nine Rambouillet rams used in the subsequent progeny-test.

	Body weight, kg							Fiber diameter, µm	
Sire	Initial	Final	ADG, kg	GFW[a]	Y[b]	CFW[c]	SL[d], cm	Side	Britch
1	58.6	100.0	0.29	3.19	52.2	1.67	4.48	21.9	25.5
2	55.0	116.8	0.44	3.85	43.7	1.68	4.58	20.2	22.9
3	60.0	121.8	0.44	4.25	55.1	2.34	5.46	27.0	29.6
4	62.7	126.4	0.45	3.64	59.8	2.18	4.38	26.5	30.5
5	46.4	95.0	0.35	3.68	48.3	1.78	4.77	23.7	26.2
6	56.4	111.4	0.39	4.71	56.8	2.67	5.46	24.7	28.9
7	68.2	119.6	0.37	5.02	52.7	2.65	5.26	22.2	24.0
8	47.7	86.4	0.28	2.79	57.0	1.59	4.58	21.9	24.8
9	63.6	131.4	0.48	4.85	52.5	2.54	4.38	26.0	30.4
Mean	57.6	112.1	0.39	4.00	53.1	2.12	4.82	23.8	27.0
Maximum	68.2	131.4	0.48	5.02	59.8	2.67	5.46	27.0	30.5
Minimum	46.4	86.4	0.28	2.79	43.7	1.59	4.38	20.2	22.9

[a] GFW = grease fleece weight, kg (adjusted to 140 d).
[b] Y = lab scoured yield, %.
[c] CFW = clean fleece weight, kg (adjusted to 140 d).
[d] SL = Staple length (adjusted to 140 d).

unlimited intake of high quality feed, will be realized in the offspring reared under different conditions. Therefore, this study was designed to estimate the relationship between sire's central test performance and progeny performance. Traits analyzed included post-weaning average daily gain, fleece weight, wool fiber diameter, and wool staple length. Progeny traits were measured under conditions similar to those of the central test and on the native range.

Materials and Methods

Animal Management

Thirty-six Rambouillet ram lambs (progeny of 9 centrally tested sires) were used to evaluate the effect of sire's central test performance on fleece weight, fiber diameter, staple length, and weight gain under two management systems and during two distinct periods in the lives of the progeny. All sires were centrally performance tested at the Texas Agricultural Experiment Station central ram performance test in Sonora, TX during the 1993-1994 test (Waldron and Lupton, 1994). Sires were shorn and began the performance test in September and remained on test until February. During the test, side and britch fiber diameters were measured in January. Fleece weight and staple length were measured in February, representing 140 d of fleece growth. Body weight gain was measured as 140-d ADG (September to February). The nine sires were unrelated and represented a wide range of performance and wool characteristics as measured on the central performance test (Table 1).

The sires were mated to a flock of 4-yr-old commercial Rambouillet ewes in September and October of 1994 on the Winters Ranch near Brady, TX. Individual ewe body weights were recorded at the start of the breeding season. The flock of 270 ewes was divided into six categories based on body weight. Ewes were then divided randomly, within body weight category, into nine breeding groups so that the mean body weight (BW) of each group of ewes was similar. Matings occurred in single-sire pastures. Mid-side wool samples were obtained from each ewe in January 1995 prior to lambing. Fleece weights of the ewes were recorded in April, 1995. Lambs were born between January 27, 1995 and March 9, 1995. All lambs were identified with their dams, ear tagged, and weighed within 18 h of birth. The number of ram lambs per sire group varied from 9 to 16 when lambs were approximately 60 d of age. Each sire group was divided into top and bottom halves based on visual appraisal to exemplify the process breeders may use in selecting rams to submit to a central performance test. Because of limits on labor and facilities, four ram lambs per sire group were chosen at random from the top half of each sire group for this study. Lambs were weaned at a mean age of 120 d and placed on a growing ration for 30 d, then placed on native range until the initiation of the experiment.

When ram lambs averaged 195 d of age (October 1995), they were randomly allotted to pens within sire group (two rams per pen and two pens per sire) with shade and fresh water available. Rams were given ad libitum access to the test diet (Table 2) for a 14-d adjustment period. During the adjustment period, mid-side and britch wool samples were taken from each test animal and they were dosed with Ivomec (Ivermectin, Merck and Co., Rahway, NJ). All rams were shorn on

Table 2. Ingredient composition of diet[a] used in the feedlot portion of the study.

Ingredients	Percent (as fed)
Alfalfa, dehy (17%)	28.24
Cottonseed hulls	23.37
Cottonseed meal	7.30
Molasses, cane	4.87
Sorghum, grain	24.34
Soybean meal (44%)	7.30
Ammonium chloride	.49
Calcium carbonate	.49
TM[b] Salt	.97
Aurofac 10	.15
Vitamin A	.05
Binder	2.43
Total	100.00

[a] Diet is identical to the ration used at the Sonora Ram Test.

[b] TM = trace mineral premix. The percent ingredients of the premix are as follows: sodium chloride, 64.7; potassium chloride, 19; sulfur, 10; zinc oxide, .387; vitamin A (30,000 IU/g), .73; vitamin D (30,000 IU/g), .093; vitamin E (125,000 IU/g), .72; chlortetracycline (50,000 IU/g), 3.0; and molasses, 1.5.

one day, three days prior to the initiation of the test. At the initiation of the test, BW was recorded on two consecutive days and the average served as the initial weight. All test rams were allowed ad libitum access to the same diet (Table 2) for the duration of the 140-d feedlot experiment. This diet is the same as that used at the Texas Agricultural Experiment Station's Ram Performance Test in Sonora, Texas, and meets or exceeds the NRC requirements for replacement ram lambs (NRC, 1985). Physical condition of each animal was observed daily and sick animals were treated and noted for further observations.

Rams were weighed and dye-bands (Wheeler et al., 1977) were applied to a 7-cm strip at the mid-side of each ram at 28-d intervals. Upon completion of the feedlot portion of the trial (2/28/96), dye-banded samples were removed at skin level and britch wool samples were also taken. Rams were weighed on d 139 and 140 and then shorn on d 140. The consecutive body weights were averaged to adjust for rumen fill. Grease fleece weights were subtracted from the final BW to obtain the true final BW. Two rams from different sires died of unknown causes during the feedlot trial. Data from these two rams were not included in the analysis.

On February 28, 1996 all rams were placed in one pasture and were periodically rotated through four pastures to ensure adequate forage intake throughout the 140-d range trial. Due to the time of year, forage quantity was abundant, but protein levels were low. Therefore, the rams were supplemented with .46 kg ram^{-1} d^{-1} of a 20% crude protein range cube. The rams were supplemented only during the first two weigh periods (0 to 56 d) of the range trial because near the conclusion of the second weigh period it rained (11.7 cm), range conditions improved quickly, and supplementation was no longer needed. Clean, fresh water, and mineral supplements were available to all animals ad libitum. Rams were observed daily, and sick animals were treated and noted for further observation. The purpose of the range trial was primarily to evaluate the relationship between sire's central test performance and progeny performance for wool traits, although ADG and BW were also analyzed.

Rams were weighed and dye-bands were applied every 28 d as in the feedlot trial. Final BW for the range trial was calculated as for the final BW of the feedlot trial. One ram, from a third sire, died on d 3 of the range trial from injuries sustained in a fight. His data were included in the analysis for the feedlot trial but not the range trial.

Wool Analysis

Wool grown during the third period, in both the feedlot and range trials (third dye-band) was used as the measure of fiber diameter. The third period of the pen trial corresponded to the time at which fiber diameter was measured on the sires during the central performance test. The third period of the pasture trial was used because the time from the start of this portion of the trial to wool sampling was the same as for the pen trial. The OFDA (IWTO, 1995), was used for determining average fiber diameter (AFD) of the side and britch wool samples. Core samples were removed from the entire shorn fleece (Johnson and Larsen, 1978) to determine percentage yield of the fleece. The percentage yield was determined by washing subsamples of the core samples using a standard method (ASTM, 1995a). Grease fleece weight and yield percentage were used to calculate clean fleece weight (CFW). Average staple length (SL) for the entire shorn fleece was measured

Table 3. Performance of ram progeny in feedlot and range environments.

	Mean	SD	Minimum	Maximum
Feedlot environment: n = 34				
ADG[a], kg/d	35	.05	.21	.48
Final BW, kg	104.8	10.43	78.6	125.9
CFW[b], kg	4.5	0.06	2.8	6.1
Yield, %	48.9	3.12	39.4	57.8
SL[c], cm	4.5	.37	3.7	5.1
AFD[d], microns	23.6	1.73	19.8	27.7
Range environment: n = 33				
ADG[a], kg/d	-.08	.05	-.22	.03
Final BW, kg	93.6	7.22	78.6	110.0
CFW[b], kg	3.1	0.05	2.1	4.6
Yield, %	43.5	4.45	35.4	53.2
SL[c], cm	3.6	.42	2.6	4.3
AFD[d], microns	21.5	1.64	18.3	25.9

[a] ADG = 140-d Average daily gain.
[b] CFW = 140-d Clean fleece weight.
[c] SL = 140-d Staple length.
[d] AFD = Average fiber diameter.

by randomly removing 20 staples from the entire fleece, measuring them in a standard manner (ASTM, 1995b) and calculating average length of the staples. All wool analyses were conducted at Texas Agricultural Experiment Station, Wool and Mohair Research Laboratory, San Angelo, TX.

Statistical Analysis

Differences between feedlot and range performance means were tested using PROC TTEST (SAS, 1989). An F statistic was calculated to test the equality of variances between environments. For the estimation of the relationship between sire's central test performance and progeny performance, data were analyzed within environment with PROC MIXED (SAS, 1992). The model used for each trait included a fixed effect for type of birth of lamb (single or multiple), a linear regression for age of lamb in days at the start of the feeding period, a covariate for sire's performance, a covariate for dam's performance, and random effects for sire and residual error. Starting weights of the lambs were not used as covariates because it was assumed that starting weight differences were a function of genetic and environmental differences and removing some of the genetic variation, due to sire, of correlated traits by using starting weight as a covariate could bias results. Covariates for dam's performance were used to account for variation among the mates of the sires. The covariate for dam's performance was dam's body weight at breeding for gain and final BW, dam's grease fleece weight for fleece weight and staple length, and dam's fiber diameter for fiber diameter.

The covariate of sire's performance on central test (gain, final BW, clean fleece weight, yield, staple length, or fiber diameter) was used to relate sire's central test performance to progeny performance. The random effect of sire was included in the model in order to account for covariance among paternal half-sibs (Henderson, 1984; Waldron et al., 1990). Correlation coefficients were calculated between feedlot and range performance.

Results and Discussion

Animal Performance and Wool Characteristics

The mean performances of rams in the two environments are shown in Table 3. Average daily gains for the feedlot and range trials were .35 (min = .21, max. = 0.48) and -.08 kg/d (min. = (-.22), max = .03), respectively. Traits measured on the rams in the feedlot environment had means similar to those of the sires on the central test (Table 1). As expected, the performance for all traits was lower ($P < .001$) when measured under range conditions. However, the sample variances were similar across environments ($F > .3$) for ADG, clean fleece weight, SL, and AFD, which suggests that the phenotypic variation among rams was not a function of environment for these traits. Sample variance was larger ($F < .05$) in the feedlot environment for final BW, and larger ($F < .05$) in the range environment for yield.

Regression Analysis for Offspring Versus Sire Traits.

The estimated regression coefficients relating sire's central performance to progeny performance are shown in Table 4. The estimate for ADG measured on range was the only relationship that was negative and different from zero ($P = .058$). With the exception of fleece yield in the

Table 4. Regression coefficients of offspring performance on sire's central test performance and correlations of offspring performance between environments.

Item	Feedlot trial			Range trial			
	Regression coefficient	SE	P	Correlation between environments	Regression coefficient	SE	P
ADG[a]	+.46	.12	.001	-.75	-.23	.11	.058
Final BW	+.46	.11	.001	.89	+.29	.09	.003
CFW[b]	+.34	.09	.001	.29	+.23	.11	.053
Yield	+.12	.11	.291	.57	-.00	.16	.981
SL[c]	+.33	.13	.019	.27	+.09	.17	.603
AFD[d]	+.41	.09	.001	.85	+.39	.09	.001

[a] ADG = 140-d Average daily gain.
[b] CFW = 140-d Clean fleece weight.
[c] SL = 140-d Staple length.
[d] AFD = Average fiber diameter.

range environment, all other estimates were positive. Estimates for all traits measured in the feedlot environment, except for fleece yield, were different from zero ($P < .05$). These results indicate that sire's central test performance was a valid predictor of progeny performance when measured in a similar feedlot environment. Waldron et al. (1990) did not find a significant relationship between sire's central test performance (ADG) and progeny performance using 18 Suffolk rams from three separate 63-d central tests. Waldron et al. (1990) suggested that a 63-d test was not long enough to be free from pre-test environmental effects and therefore the accuracy of central test data for predicting genetic value for postweaning ADG was limited. Bradford and Spurlock (1972) using 17 sires from one flock rather than from a central performance test, reported correlations of sire weights and gains at different ages with progeny growth rate, and reported that sire's postweaning BW (120-d wt, 6-mo wt, or yearling wt) was a better predictor of progeny growth rate than sire's 46-d post weaning gain. Schwulst et al. (1996) classified 12 Suffolk rams that had been on a performance test as either high- or low-ranking based on an index that gave equal emphasis to postweaning ADG and weight per day of age. They found that lambs sired by high-ranking rams had greater postweaning ADG than lambs sired by low-ranking rams. The magnitude of the difference in sire's ADG or weight per day of age was not reported (Schwulst et al., 1996). The central test from which the sires of the present study were selected was approximately twice as long (140 d vs 63 d) as those typically conducted in the Midwest (Waldron et al., 1989). Additionally, central ram performance tests in the Midwest began when rams were approximately 3 mo old, whereas the Texas Rambouillet test began when rams were from 6 to 10 mo old. The different length of test and/or the age at the start of the test may have contributed to the difference in results.

Our results agree with those of Shelton (1959). He also reported a positive relationship between sire's central test wool performance and offspring performance, but his sire-offspring regression coefficients were markedly lower than ours obtained from the feedlot environment. One difference between our data and Shelton's (1959) is that we tested intact rams under a similar environment as their sires, whereas his data were obtained from ewes and wethers raised under range conditions. The central testing period was even longer (>300 d) in the 1950s when Shelton sampled rams from the central test for the 1959 report.

The regression estimates for growth rate and wool quantity measurements (FW and SL) obtained in the range trial were smaller than those of the feedlot trial. However, sire's fiber diameter, as measured on central test, was a significant predictor of progeny fiber diameter in both the feedlot and range environments. The negative mean ADG on range (Table 3) is not representative of a normal growth pattern, but was not unexpected for the present design where rams were fed ad libitum for 140 d, and then subject to the range environment for 140 d. The negative relationship between sire's central test ADG and progeny ADG on range (Table 4) may be a result of the sequence of feeding environments of the rams. Because of the animal's ability to mobilize body reserves, the results from the analyses of ADG and BW data of the range trial must be interpreted with caution. The estimated correlation coefficients between feedlot and range performance for final BW and all wool traits were positive (Table 4). However, the estimated correlation between ADG on the feedlot trial and ADG on the range trial was -.75. This indicates that change in body weight during the 140-d range trial appears to be a function of ADG during the feedlot trial. The rams with high gains in the feedlot tended to lose more weight during the range portion of the trial. The strong negative correlation between feedlot and range ADG suggests that the high ADG rams were accumulating energy reserves during the feedlot trial and expending those reserves during the range trial. Because the low-nutrition range trial followed the ad libitum-feeding feedlot trial, the negative regression of range ADG on sire's central test performance ADG does not, therefore, suggest that rams with higher central test ADG will produce progeny with lower ADG under range conditions, except if the range ADG is measured immediately after a long feeding period of high body weight gains. The strong positive correlation between final BW in the feedlot and range environments was expected because of the part-whole relationship of the two weights. Sire's final BW on central performance test was positively related to progeny final BW in both trials ($P < .01$). Because the rams' growth rate on range was measured after the feedlot trial, the rams were closer to maturity during the range trial. If the growth curve was changing shape at this age, differences may have been observed as a function of maturity. The stage of maturity was confounded with the switch from feedlot to range environments in this study because the rams were being compared at two different physiological stages in their lives. Shelton's (1959) result (estimated regression of .11 between central test ADG and weaning weight under range conditions) is not comparable to the regression of progeny ADG on central test ADG of the present study because weaning weights were obtained from lambs grown entirely in a range environment rather than grown in a high-nutrition environment followed by a low-nutrition environment and the progeny traits were measured at different stages of life (preweaning versus postweaning). The positive regression coefficient relating progeny final BW to sire's central test final BW, indicates that even after being in the range environment for 140 d, and losing weight, sons of sires with high central test final BW were heavier.

Because wool is not an energy store that can be mobilized, as body reserves are, wool traits as measured on the range trial, were not affected in the same way as ADG. The relationship between sire's central test AFD and progeny AFD was strong in both environments. This is in contrast to the result for fleece yield, where a significant relationship was not found in either environment. However, progeny CFW, which is a function of yield, was positively related to sire's central test CFW. Although the means of CFW and AFD were lower on the range, the positive estimates of the relationship between sire's performance and progeny performance indicate that central test performance was indicative of progeny performance, even in the range environment for these traits. These results for CFW and AFD suggest that it is effective to use a favorable environment for a central performance test even though progeny may be raised in a range environment.

The regression coefficients of Table 4 can be multiplied by two to obtain heritability estimates. The heritability estimates are generally on the high side of the range of previous estimates (Young et al., 1960; Fogarty, 1995). However, the heritability estimates for fleece yield were lower, especially for the range environment, than previously published estimates (Young et al., 1960). Given the small number of sires used in the present study, the lack of precision (i.e. large standard errors) was not unexpected. The feedlot environment was chosen to be similar to the environment in which the sire's central test performance was measured. The similarity of environments and small amount of environmental variation in the feedlot environment may have contributed to the magnitude of the sire-offspring regression coefficients (Table 4). Lasslo et al. (1985) reported a greater response to selection for increased lamb weaning weight in a more favorable environment than in a range environment.

The results from the range trial of the present study may have been influenced by its design where the range trial immediately followed the feedlot trial and the same animals were used in both trials. The resulting confounding of environment and age period precludes estimation of effects of environment and age period. Contemporary evaluation of samples of progeny in the two environments would be necessary to obtain estimates free of this confounding.

Conclusions

A ram's 140-d central test performance was a valid indicator of offspring performance under similar conditions. However, sire's test performance was not as strong an indicator of offspring performance under range conditions when evaluated immediately after a 140-d performance test under good nutrition. The value of using sire's AFD on central test to predict progeny AFD was similar in both environments. Central performance test evaluations can effectively rank rams for their offspring's postweaning growth rate and wool traits.

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Supplemental Feeding Interval for Adult Ewes

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Summary

Two range trials (one fall and one winter; 91 ewes) and a confinement trial (36 ewes) were conducted to determine effects of supplementing adult Rambouillet ewes at 1-, 2- (or 4-), and 7-d intervals. In each range trial, pregnant ewes were assigned to three pasture groups and within each pasture group to four feed treatments. Feed treatments were control (Control; no supplemental feed), cottonseed meal (CSM; 25% of protein requirement), energy equivalent (Low; one-half protein and equal energy with CSM), and protein equivalent (High; equal protein and twice energy with CSM). The three pasture groups were penned either at 1-, 4- or 7-d intervals and fed individually. The ewes were rotated among pastures at 3-wk intervals to minimize pasture effects. The fall and winter trials lasted 81 and 73 d, respectively, during which parturition occurred. Data collected included initial and final weights of ewes. A confinement trial (49 d) was conducted with 36 adult nonpregnant ewes fed oat hay free-choice and .23 kg/ewe (as fed) daily equivalents of cottonseed meal (CSM) at 0, 1-, 2-, and 7-d intervals to determine patterns of serum urea nitrogen (SUN; indicating efficiency of protein utilization), feed intake, and live body weight change. In the range trials, supplementation reduced ($P < .05$) weight loss compared with Control when feeding was daily. However, there was a feed treatment x feeding interval interaction ($P = .098$) showing that the effectiveness of CSM and Low did not differ ($P = .21$; $P = .58$) with feeding interval; wherea, the High treatment was less ($P = .01$) effective when fed at less frequent intervals. In the confinement trial, the SUN levels in ewes fed at 7-d intervals remained higher ($P < .04$) than Control until d 5 and not lower ($P > .17$) than 1-d until d 6 after the feeding event. These data show that sheep, like cattle, can be fed a protein supplement effectively as infrequently as one time per week.

Key words: sheep, feeding interval, serum urea nitrogen.

Introduction

Sheep on rangeland obtain nutrients primarily as they consume various plants and plant parts from the landscape. These plants differ in season of growth, length of growth and dormancy periods, and in presentation (low growing, herbaceous, shrubs, etc). The proportion of plant types in a particular location is determined by climate, site, and current and previous use. These factors shape the range vegetation to provide diet quality and quantity that may exceed or fail to meet the animal's requirements for desired productivity. Supplemental feeding is a means of providing limiting nutrients during deficient periods to promote productivity.

Supplements can be provided as meals, pellets, blocks, liquids, or gels. The form of feed and the delivery system of choice depend on the nutritional value of the feed, price, and convenience. Whereas certain feeds are designed for self-feeding using physical form or added ingredients to limit consumption, other feeds are "hand fed" to provide the desired amounts. Although in some instances hand-fed supplements are of greater value to the animal, the expense and inconvenience of delivery often eliminate them as alternatives. Cattle can be supplemented effectively as infrequently as once per week thereby reducing the costs of distribution of hand-fed supplements (Huston et al., 1997). A study was conducted to determine whether feeding interval affected the value of supplemental feed for ewes grazing rangeland during either fall or winter.

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Table 1. Treatment assignments in fall and winter supplementation in ewes

Past. no.	Group	No. ewes[a]	Feeding frequency	Supplement type[b]	Feeding level (as fed) g/d[b]	g/event
1	1	10	Control	-	0	0
1	2	10	1-d	CSM	114	114
1	3	10	1-d	20%	105	105
1	4	10	1-d	20%	227	227
2	5	10	Control	-	0	0
2	6	10	4-d	CSM	114	454
2	7	10	4-d	20%	105	420
2	8	10	4-d	20%	227	908
3	9	10	Control	-	0	0
3	10	10	7-d	CSM	114	795
3	11	10	7-d	20%	105	735
3	12	10	7-d	20%	227	1589

[a]Number of ewes in the fall trial (Trial 2) were 9 per group.
[b]A supplement containing 20% crude protein (calculated value; 65% sorghum, 35% cottonseed meal) was fed at either 105 (Low) or 227 (High) g/ewe/d.

Table 2. Changes in live body weight of ewes lambing during either fall or winter

Item	Lambing period Fall	Winter	SE[a]
Number of ewes	49	42	
Live body weights, kg			
Initial	61.8	70.6	
Final	56.5	58.4	
Change	-5.3	-12.2	.49

[a]Standard error.

Materials and Methods

Two range trials (fall and winter) and one confinement trial were conducted to determine the feasibility of feeding supplements of different types and in different amounts to ewes on low-quality roughage diets at intervals less frequent than daily. The rangeland at the Texas A&M University Agricultural Research & Extension Center at San Angelo is Angelo and Mereta clay loam with 0 to 1% slope. The vegetation of the area is comprised of perennial, warm season grasses with smaller amounts of cool season and succulent (Opuntia sp.) species. The two range trials were conducted with adult Rambouillet ewes (ages = 1 to 4 yr) that were subjected to breeding between May 27 and July 7 and between August 27 and October 6, respectively. A single flock of ewes was bred during the two breeding periods by six rams fitted with marking harnesses. The first breeding period was terminated when the predetermined number of ewes (n = 120) were marked. Only ewes with breeding marks were included in the study. The remaining ewes were bred similarly during the fall for winter lambs. Several ewes that received breeding marks were not pregnant or were not observed to give birth and subsequently were eliminated from the data.

Trial 1. The ewes were assigned to 12 groups of 10 ewes/group equalized for age, beginning live body weight, and breeding date. Four groups were assigned to each of three pastures. The four groups in each pasture were designated as control (Control; no supplemental feed), cottonseed meal (CSM; 114 g/ewe/day providing approximately 25% of the crude protein requirements of ewes in late pregnancy; NRC, 1985), a low level of a 20% CP supplement (65:35 mixture of sorghum grain:cottonseed meal; Low; equal digestible energy (DE) with CSM but lower supply of CP), and a high level of the 65:35 mixture (High; equal CP with CSM with approximately twice the DE supply). Between September 20 and December 13, the ewes in the three pastures

Table 3. Changes in live body weight of ewes either not fed or fed one of three supplements during late pregnancy and early lactation on rangeland

	Feed treatments				
Item	Control	CSM	Low	High	SE[a]
Number of ewes	15	21	27	28	
Live body weights, kg					
Initial	64.1	68.0	66.3	66.5	
Final	52.5	60.4	58.3	58.7	
Change	-11.6	-7.6	-8.0	-7.8	.69

[a]Standard error.

Table 4. Changes in live body weight in ewes fed at different intervals during late pregnancy and early lactation on rangeland

	Feeding interval			
Item	1-d	4-d	7-d	SE[a]
Number of ewes	24	26	26	
Live body weights, kg				
Initial	68.5	66.0	66.2	
Final	61.0	59.8	56.6	
Change	-7.5	-6.3	-9.7	.67

[a]Standard error.

were gathered either daily (1-d), every 4 days (4-d), or every 7 days (7-d), and treatments were applied on an individual animal basis using individual feeding stalls (Table 1). On arrival at the feeding barn, the ewes to be fed (30 or less in each pasture) were placed in feeding stalls (30 stalls are available) and given the appropriate supplements. After an ample amount of time was allowed for the ewes to consume all of the feed offered, the ewes were released back into the pasture. Control ewes were gathered along with the supplemented ewes, held in a pen during the feeding period, then released back to pasture along with the other ewes. The feeding events usually occurred during the early afternoon and lasted approximately 2 hours. The ewes in the 4-d and 7-d groups were fed 4 and 7 times the daily equivalent at each feeding event. A negative control group (Control) was included in each pasture to be used to correct for pasture and other nontreatment effects. The ewes were rotated among pastures to minimize the pasture effects. Lambing began October 23. Beginning and final live body weights of ewes (unshrunk) were recorded. Only ewes with live lambs at the termination date (December 13) were included in the data.

Trial 2. Ewes similar to those described for Trial 1 were used except the ewes (9/group) were bred during the fall for lambing during February. All treatment assignments and experimental methods for this trial were identical to those of Trial 1 (Table 1) but were conducted between January 4 and March 18. Lambing in Trial 2 began January 22.

Trial 3. Thirty-six nonpregnant ewes were divided into 12 groups to receive four treatments in three pens of three ewes per pen to study the effects of feeding cottonseed meal at different intervals on weight change, intake of roughage, and serum urea nitrogen (SUN). The groups were balanced for ewe weight and age. The ewes were fed wheat straw (approximately 3.5% CP and 1.4 Mcal/kg DE) free choice for 22 d then were fed oat hay (8% crude protein and 2.4 Mcal/kg digestible energy) for 21 d before treatments were applied in addition to free choice feeding of the oat hay for 28 d. The four treatments included a control group (Control; no CSM), CSM daily (1-d; 227 g/ewe of CSM fed daily), CSM fed every 2 d (2-d), and CSM fed every 7 d (7-d). Feeding levels for 2-d and 7-d were two and seven times the 1-d level, respectively. During the first week of treatment, blood samples were drawn by venipuncture at 0800 on day 0, 1, 2, . . ., 7 in regard to first feeding of supplements. Serum was removed and frozen until analysis for urea nitrogen was conducted at a later date using a modification of the method of Chaney and Marback (1962). Daily forage consumption (pen basis) was measured during the 21 d before treatment and during the 28-d treatment period by weighing back refusals daily. The cottonseed meal was fed at 0800 in a separate feed trough that was large enough to accommodate concurrent feeding by all of the ewes in the group. Ewe weights were recorded prior to feeding of wheat straw, at the beginning of feeding of oat hay, at beginning of treatment, and at termination.

Statistical analysis. The weight data for Trials 1 and 2 were analyzed using the General Linear Model (GLM; SAS, 1991) with season, feed treatment, and feeding interval as main effects. The main effects and all possible interactions were tested. The control treatment ewes were included in pasture groups (feeding interval) for testing of main effects but were removed for calculating the standard error (SE) for comparisons among feeding intervals. After significant interactions were detected, condensed analyses were conducted within each season for treatments at each feeding interval and feeding interval for each treatment. The data were corrected for pastures using the Control ewes and relative values for the ewes on other treatments to Control ewes within those pastures. Also, because initial live body weights differed among treatments

Table 5. Effects of feed treatment and feeding interval on changes in live body weight (kg) of ewes bred for fall lambs (Trial 1; data corrected to standard initial weight and control treatment)

	Feeding treatment					Contrasts[b]		
Item	Control	CSM	Low	High	SE[a]	1	2	3
Number of ewes	9	11	16	13				
Feeding interval								
1-d	-7.9	-3.8	-1.6	-0.5	2.02	.04	.29	.69
4-d	-7.9	-4.7	-6.0	-5.7	1.59	.34	.55	.91
7-d	-7.9	-3.4	-5.5	-9.9	1.05	.22	.01	.01
SE[a]		1.68	1.52	1.66				
Contrasts[c]								
1		.90	.06	.005				
2		.63	.82	.13				

[a]Standard error.
[b]Contrasts (P - values)
1) Control vs fed groups (CSM, Low, and High)
2) CSM vs Low and High
3) Low vs High
[c]Contrasts (P - values)
1) 1-d vs less frequent (4-d and 7-d)
2) 4-d vs 7-d

after the unuseable ewes were eliminated, the weight change data for the condensed analyses were corrected for initial body weight. Because the feeding treatments were individually applied, the individual ewe was considered the experimental unit. Data from Trial 3 were analyzed using GLM with feeding interval (weight and intake data) and both feeding interval and day (SUN data) as main effects. Rep (pen) within feeding interval was used as error term. Contrasts were used to compare individual or groups of means as indicated in footnotes to the tables.

Results and Discussion

Least squares means for the main effects of Trials 1 and 2 are shown in Tables 2, 3, and 4. Data from many of the ewes that were assigned to treatments in the range trials were deleted because they either were not pregnant, lost their lamb(s), or did not adjust to the feeding routine (would not eat in the individual feeding stalls). Fall-lambing ewes had lower initial live body weights but lost less body weight while on the feeding regime compared with winter-lambing ewes. This was not surprising because dietary components of range ewes in the region in which the experiment was conducted commonly are of higher quality during fall compared with either summer or winter (Huston et al., 1981). This higher quality diet during fall would lower weight loss in ewes that lambed and increase live body weight in ewes in early to mid pregnancy. Therefore, fall-lambing ewes would weigh less in late summer while approaching late pregnancy but maintain weight better during early lactation compared with winter-lambing ewes that would be more heavily conditioned during mid to late pregnancy but lose weight quickly after parturition when requirements would exceed the nutritional value of the diet. These expected patterns are consistent with what actually occurred (Table 2). Fed ewes lost less ($P < .01$) live body weight than Control, but losses did not differ among fed groups (Table 3). Ewes that were gathered and fed at 7-d intervals lost more ($P < .05$) weight than the 1-d and 4-d groups (Table 4). However, interactions between feed treatment and feeding interval ($P = .099$) and between season and feeding interval ($P = .006$) suggested that condensed analyses should be conducted.

Results from the fall trial (Trial 1) showed an interaction between type of feed and feeding interval (Table 5). Ewes that were supplemented daily lost less ($P = .04$) live body weight than Control irrespective of what supplement was fed. Ewes fed at weekly intervals (7-d) did not differ ($P = .22$) from Control, but the ewes fed the lower protein supplement at either low or high levels (Low and High, respectively) lost more ($P < .01$) body weight than those receiving CSM. Moreover, the higher fed group (High) lost more ($P < .01$) weight than the lower fed group. No differences were detected among feed treatments within the 4-d group. Within the CSM treatment, feeding interval did not affect weight loss either when 1-d was compared with less frequent ($P = .90$) or 4-d to 7-d ($P = .63$). However, for the low protein supplements, both Low and High were less ($P = .06$ and $.005$, respectively) effective when fed less frequently than daily. High tended to be less ($P = .13$) effective when fed at 7-d compared with 4-d intervals.

Table 6. Effects of feed treatment and feeding interval on changes in live body weight (kg) of ewes bred for winter lambs (Trial 2; data corrected to standard initial weight and control treatment)

	Feeding treatment					Contrasts[b]		
Item	Control	CSM	Low	High	SE[a]	1	2	3
Number of ewes	6	10	11	15				
Feeding interval								
1-d	-14.3	-11.3	-11.7	-8.1	.85	.01	.40	.005
4-d	-14.3	-6.3	-7.6	-7.9	1.47	.008	.43	.90
7-d	-14.3	-11.3	-11.0	-10.4	1.40	.13	.70	.75
SE[a]		1.13	1.19	1.24				
Contrasts[c]								
1		.29	.14	.49				
2		.0085	.11	.20				

[a]Standard error.
[b]Contrasts (P - values)
1) Control vs fed groups (CSM, Low, and High)
2) CSM vs Low and High
3) Low vs High
[c]Contrasts (P - values)
1) 1-d vs less frequent (4-d and 7-d)
2) 4-d vs 7-d.

Table 7. Serum urea nitrogen concentrations (mg/100 ml) in ewes fed hay and supplemented with cottonseed meal at increasing intervals (Trial 3)

	Treatments					Contrast[b]		
Days	Control	1-d	2-d	7-d	SE[a]	1	2	3
0	14.9	12.1	15.9	13.5	2.64	.52	.52	.50
1	16.8	18.2	24.9	36.5	3.99	.001	.0001	.0001
2	14.6	19.1	19.8	26.2	4.19	.02	.06	.03
3	13.0	18.1	24.9	19.5	2.66	.0002	.52	.007
4	13.3	17.0	18.3	17.2	2.19	.009	.95	.04
5	13.6	18.7	22.6	15.5	2.77	.008	.17	.42
6	15.3	20.1	20.1	14.5	2.35	.07	.008	.70
7	15.2	20.7	22.1	13.3	2.29	.03	.0006	.32
SE[a]	1.82	1.78	4.41	2.33				
Contrasts[c]								
1	.21	.001	.02	.0001				
2	.80	.001	.28	.0001				
3	.20	.001	.01	.002				
4	.28	.001	.50	.06				
5	.38	.001	.07	.29				
6	.82	.001	.24	.58				
7	.84	.001	.09	.94				

[a]Standard error.
[b]Contrasts (P - values)
1) Control vs fed groups 1-d, 2-d, and 7-d
2) 1-d vs 7-d
3) Control vs 7-d
[c]Contrasts (P - values) day 0 vs each of days 1 through 7.

Table 8. Body weights and intake in ewes fed hay and supplement at increasing intervals (Trial 3)

Item	Treatments				SE[a]	Contrast[b]			
	Control	1-d	2-d	7-d		1	2	3	4
Live body wt, kg									
Initial wt	60.9	63.2	63.7	64.1	3.79				
Final wt	64.3	66.2	65.6	67.8	3.89				
Wt change	3.4	3.0	2.0	3.9	1.57	.62	.26	.53	.78
Intake, kg/d									
Hay[c]	1.88	1.87	1.58	1.81	.06	.006	.001	.25	.24
CSM	.00	.23	.23	.23	.00				
Total	1.88	2.10	1.81	2.04	.06	.01	.17	.25	.002

[a]Standard error.
[b]Contrasts (P - values)
1) Control vs fed groups 1-d, 2-d, and 7-d
2) 1-d vs 2-d
3) 1-d vs 7-d
4) Control vs 7-d
[c]Oat hay contained 8% crude protein and 2.4 Mcal/kg digestible energy.

In the winter trial (Trial 2), supplemented ewes lost less (P = .01, P = .008, and P = .13) live body weight than Control, when fed daily, every 4 days and every 7 days, respectively. Losses differed among fed groups only when feeding was daily (Table 6). At the daily feeding interval, the High group lost less (P < .005) live body weight than Low which did not differ from CSM (11.7 and 11.3 kg, respectively).

Three inferences are indicated in the data from the winter trial. Feeding reduced live body weight loss irrespective of feeding frequency. The low-protein supplement fed at a high level appeared less effective when fed at weekly intervals which agrees with the results of the fall trial (Table 5). Feeding at 4-d intervals appeared the most effective feeding frequency.

Results of Trial 3 (Tables 7 and 8) indicated that infrequent feeding altered the serum urea nitrogen concentration (SUN) from the relatively uniform pattern found with daily feeding and did not depress either hay intake or weight gain. All feeding intervals elevated the SUN above control levels. The 2-d feeding resulted in an every-other-day pattern of higher and lower SUN. Ewes supplemented at 7-d intervals showed very high SUN values on days 1 and 2 following feeding then a slow decline in SUN back to prefeeding levels about day 7. SUN values for the 7-day ewes were not statistically different from Control nor initial 7-d levels by d 5 and afterwards. Differences in live body weight changes were not detected, possibly because of the short experimental period. However, it appeared that every-other-day feeding depressed (P < .001) the voluntary intake of hay compared to daily feeding.

These results confirm that infrequent feeding of a range supplement, having been sound management in beef cattle (McIlvain and Shoop, 1962; Melton and Riggs, 1964; Wettemann and Lusby, 1994; Huston et al., 1997), is similarly effective in sheep. Although these data do not provide conclusive evidence of the mechanisms involved, it seems reasonable that the large departure from steady state nutrition created by infrequent supplementation is tolerated by the gastrointestinal system of the grazing animal. Furthermore, the likely benefit of this intermittent "gorging" of the protein supplement lies in the ability of the ruminant to recycle nitrogen (Hume et al., 1970). The ammonia that accumulates in the rumen within a few hours of a large intake of protein (Beaty et al., 1994) is followed shortly by a similar rise in blood urea. If the rumen ammonia then decreases to a low level, urea in the blood can enter the rumen by various routes (direct diffusion, saliva) thereby increasing rumen ammonia and the resulting increases in fiber digestion and protein synthesis. Also, dietary protein that bypasses ruminal fermentation and is digested in the lower tract (undegraded intake protein; UIP) may, if absorbed in large quantities, contribute to the blood urea pool as the unused amino acids are deaminated for excretion. This short term (absorbed ruminal ammonia) and longer term (absorbed and deaminated amino acids) supply of ammonia for synthesis of blood urea may have a leveling effect on the ruminal environment and prolong the impact of intermittent, large amounts of consumed protein.

These data do not suggest that infrequent feeding should be adopted irrespective of selected feedstuffs, animal physiological status, and environmental conditions. Infrequent feeding should be avoided when potentially toxic ingredients (e.g., urea) are included in the formulation at levels computed for daily delivery. Certain animals are benefitted by near steady state conditions (e.g., ewes in late pregnancy) and may suffer from infrequent feeding practices, especially when normal grazing behavior may be interrupted by harsh weather conditions.

Conclusions

From these results we conclude that sheep, like cattle, grazing low quality forage can be supplemented effectively as infrequently as one time per week. However, caution is necessary to avoid overeating by individual ewes (bully effect) and toxicosis caused by certain ingredients (e.g., urea) that may be toxic when consumed in excessive amounts.

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The Intake and Nutritional Status of Producing Ewes Grazing Dry-Land Lucerne Pasture

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Summary

An experiment was conducted to determine the intake by dry, pregnant and lactating ewes grazing dry-land lucerne pasture at six ewes/ha in a 6-week pasture rotational system. The nutritional status of the ewes was monitored by measuring the concentrations of blood metabolites. Rumen measurements were obtained from wethers which grazed the pasture together with the ewes. Late pregnant ewes had an intake of 91.5% ($P \leq 0.05$) of that of dry ewes, whereas lactating ewes consumed 49.1% ($P \leq 0.01$) more feed than dry ewes. No deficiencies in terms of CP intake occurred with late pregnant ewes, while digestible organic matter (DOM) intake was slightly below requirement (by 21 g/ewe/day). During lactation, CP (by 76 g/ewe/day) as well as DOM (by 270 g/ewe/day) was deficient, but dry ewes ingested sufficient nutrients for maintenance. Serum urea concentrations of 30.6 mg/100 ml and 23.9 mg/100 ml were measured during late pregnancy and lactation, with corresponding 3-D-Hydroxybutyric acid (OHB) concentrations of 0.56 mmol/l and 0.45 mmol/l respectively during the same periods. Pregnant ewes maintained 24% and lactating ewes 28.6% higher OHB levels than dry ewes. Rumen NH_3-N concentrations were 22.6 mg/100 ml and 16.5 mg/100 ml during April and June, respectively. Total volatile fatty acid were 9.36 mmol/100 ml and 9.12 mmol/100 ml accordingly for April and June. It was concluded that lucerne pasture in this management scheme largely fulfilled requirements of pregnant ewes, while a moderate need for supplementary feed existed during lactation.

Keywords: lucerne pasture, producing ewes, intake, blood metabolites, rumen parameters, sheep.

Introduction

The value of legume pastures in grazing systems for ruminants is well-known. Lucerne (*Medicago sativa*) is considered one of the most productive dry-land pastures for sheep (Van Heerden and Tainton, 1987). Although the production of sheep from pasture is primarily determined by pasture yield and quality (Thomson, 1977; Elsen *et al.*, 1988), intake and production stage of the grazing animal also affect productivity (Thomson, 1977; Huston, 1983). The increased requirements of sheep during pregnancy and lactation are not always met by *ad libitum* intake levels (INRA, 1978; Freer, 1981), and nutrient deficiencies may occur.

This study was conducted to determine forage DM intake by pregnant and lactating ewes grazing dry-land lucerne pasture. Blood metabolite concentrations urea and 3-D-Hydroxyburtyric acid (OHB) (Sykes & Field, 1973; Russel, 1984) and rumen parameters (NH_3-N and VFA) were done simultaneously to quantify the contribution of the pasture to the nutritional status of the ewes.

Materials and Methods

The experiment was conducted at the Elsenburg experimental farm in the Boland area of South Africa (Southern hemisphere). Eighteen 4-year-old South African Mutton Merino (SAMM) ewes were stratified according to body weight and randomly allocated to one of two treatments. One group of ewes was mated in December after oestrus synchronization (Repromap[(R)] sponges), while the other group was left unmated. The ewes grazed dry-land lucerne pasture, where weeds were not controlled, established on a predominantly Hutton soil type, from January until January of the next year. Three hectares of pasture were separated into 6 paddocks of equal size, and grazed according to a six-week pasture rotational system at a stocking rate of 6 ewes per

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Table 1 The OM, CP and DOM intakes of dry and reproducing ewes (late pregnancy and lactation) during April and June grazing on dry-land lucerne pasture at 6 ewes/ha in a six week pasture rotational system (mean ± SE).

Intake parameters	Intake during April (Autumn)			Intake during June (Winter		
	Dry ewes	Pregnant ewes	Level of significance	Dry ewes	Lactating ewes	Level of significance
Number	9	7		9	7	
OM[a] (g/d)	1,295 ± 76	1,183 ± 85	NS[d]	880 ± 41	1,312 ± 136	$P \leq 0.01$
CP[b] (g/d)	322 ± 18	295 ± 21	NS	163 ± 7	243 ± 25	$P \leq 0.01$
DOM[c] (g/d)	889 ± 58	812 ± 58	NS	604 ± 28	900 ± 94	$P \leq 0.01$

[a] Organic matter
[b] Crude protein
[c] Digestible organic matter
[d] Not significant

hectare. Dry and producing ewes grazed the pasture as one group.

Intakes of organic matter (OMI), digestible organic matter (DOMI) and CP (CPI) were determined in nine dry and seven producing ewes during late pregnancy in April (days 135 to 145 of pregnancy) and lactation in June (day 44 to 55 of lactation). Captec Chrome[(R)] controlled release devices (CRD; Nufarm Limited, Manu Street, Otahuhu, Auckland 6, New Zealand) containing Cr_2O_3 as indigestible marker, were used (Barlow *et al.*, 1988) to determine faecal output. The ewes were administered a CRD at the beginning of each sampling month and sampled from the rectum from day eight for ten successive days at 8h00, 10h00, 12h00, 14h00 and 16h00. This time schedule was chosen to account for the diurnal variation in the percentage of chromium excreted (Brand *et al.*, 1991). The faecal grab samples collected on the different days were pooled for each ewe (the pooled samples contained equivalent masses sampled on the respective days), oven dried (105°C to a constant mass), ground (1 mm screen) and analysed for chromium (Williams *et al.*, 1962).

Daily organic matter (OM) intakes were estimated indirectly, using the quantity of OM excreted and *in vitro* digestibility of OM (IVOMD) of the pasture samples selected by oesophageally fistulated (OF) sheep, using the equation described by Morgan *et al.* (1976). Faecal output was estimated indirectly using the equation described by Read *et al.* (1986).

Ingesta samples were collected on two consecutive days each sampling month using four oesophageally fistulated wethers. Wethers were fasted overnight prior to a 30 minute sampling period the next morning. Samples were frozen after collection and dried for 72 hours at 56°C in a force-dry oven prior to analysis (Engels *et al.*, 1981). Ingesta samples were analysed for dry matter (DM), OM, crude protein (CP) (AOAC, 1985) and IVOMD (Tilley & Terry, 1963).

Figure 1 Monthly rainfall at Elsenburg during the experimental period

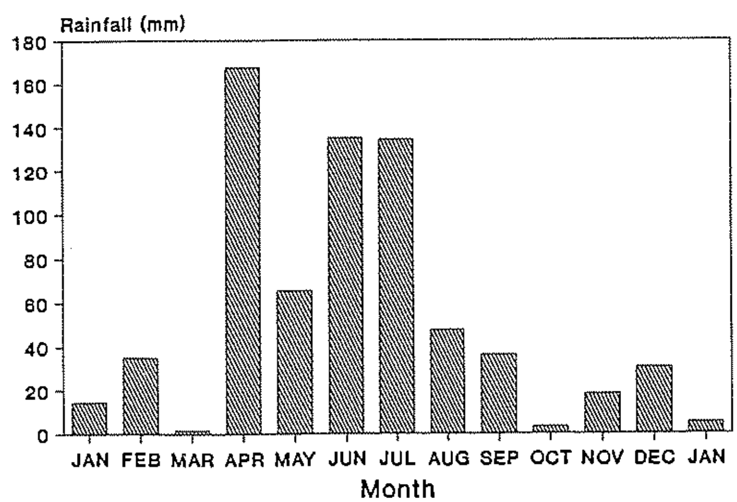

Table 2 The mean (± SE) concentrations of serum urea and serum 3-D-Hydroxybutyric acid of dry or reproducing ewes (late pregnancy and lactation) during April and June when grazing dry-land lucerne pasture at 6 ewes/ha in a six- week rotational system.

Blood metabolite concentration	April sampling			June sampling		
	Dry ewes	Late pregnant	Significance level	Dry ewes	Lactating	Significance level
Number	9	7		9	7	
Urea (mg/100 ml)	21.1±4.2	30.6±1.2	NS	23.9±1.1	23.9±1.9	NS[a]
3-D-Hydroxy-butyric acid (mmol/l)	0.45±0.02	0.56±0.04	P £ 0.02	0.35±0.02	0.45±0.03	$P \leq 0.005$

[a] Not significant.

Blood samples (20 ml) were obtained in the middle of each sampling month from nine dry and seven producing ewes by jugular venipuncture. Urea and OHB concentrations were determined in serum samples centrifuged for 20 minutes at 3 000 rpm and stored at 0°C. Analyses of serum urea (Fawcett & Scott, 1960) and serum OHB (Bergmeyer & Bernt, 1965) were done by spectrophotometry.

In the middle of April and June, ruminal samples from four rumen fistulated wethers were collected for two days at 9h00. Fistulated wethers were grazed with the ewes 14 days prior to sampling. A 0.5 mm sieve was used to separate the ruminal fluid from the solid fractions. Samples for rumen NH_3-N determination (50 ml) were acified with 10 ml 1 N H_2SO_4 and frozen prior to analysis by Auto Analyzer (Industrial Method No. 334-74 W/B; 1977) (Technicon Industrial Systems, Tarrytown, New York). Samples for VFA determination were centrifuged at 3,000 rpm for 20 minutes. One ml 10% NaOH was added to 9 ml of the supernatant, to prevent fermentation, and samples were then frozen. Prior to analysis, the samples were treated with a 25% metaphosphoric acid solution per 5 ml of sample and centrifuged at 3,000 rpm for 10 minutes. Acetic, propionic, isobutyric, N-butyric and isovaleric acid concentrations were determined using a gas chromatograph by the procedure described by Cottyn & Boucque (1968).

Differences in intake and blood metabolite concentrations between dry and reproducing ewes were tested for significance by analysis of variance. Means are accompanied by standard errors (SE) where applicable. The procedures used are described by Snedecor & Cochran (1980).

Results and Discussion

The monthly rainfall during the experimental period was typical of a Mediterranean environment (Figure 1). Pasture availability amounted to 776 kg/ha (April) and 496 kg/ha (June) during the corresponding months of pregnancy and lactation of ewes, when experimental measurements were done. Lucerne, as measured in the paddocks, while being grazed, was respectively 31.8% and 12.1% of the available pasture, while the reminder consisted mainly out of annual ryegrass. The relatively low amounts of lucerne monitored was due to the preference of sheep to select the lucerne in spite of the other available material (Brand, 1996).

The estimated OM, DOM and CP intakes of dry or pregnant and dry or lactating ewes are presented in Table 1. The pregnant ewes tended (NS) to have a slightly lower (8.5%) intake than the dry ewes in April. During lactation, an opposite relationship was found and the lactating ewes consumed 49.1% more ($P \leq 0.01$) feed per day than dry ewes in June. The relative intake between the ewes in the different physiological stages was in accordance with work by (Engels & Malan, (1979), which indicated that feed intake decreases during late pregnancy because of a reduced rumen volume, while an increased feed intake occurs almost immediately *post partum*. Cook *et al.* (1961) and Arnold & Dudzinski (1967) found that lactation stimulated ewe intake by 26% and 42%, respectively.

The requirements of a 60 kg ewe as expressed in terms of DOM needed (Jaqusch & Coop, 1971) are 474 g/day for maintenance, 833 g/day at 148 days of pregnancy and 1,173 g/day during the first 60 days of lactation (ARC, 1980). The corresponding requirements for CP (NRC, 1985) are 104 g/day for maintenance, 184 g/day during the last 6 weeks of pregnancy and 319 g/day during lactation. When the intake of DOM and CP in this study was related to these requirements, it was evident that no deficiencies in CPI occurred during April with either dry or late pregnant ewes, while DOMI was slightly below (by 21 g/ewe/day) requirements during late pregnancy. During June, both DOM and CP intakes met the requirements of dry ewes, while the nutrient intake of lactating ewes was deficient for both CP by 76 g/ewe/day and DOM by 270 g/ewe/day.

The mean concentrations of serum urea and serum OHB of the dry and pregnant ewes (April), as well as the dry and lactating ewes (June), are presented in Table 2. Pregnant ewes tended (NS) to have higher levels of urea than dry ewes during April whereas urea levels during June were equal in dry and lactating ewes. Pregnant ewes maintained 24% higher ($P \leq 0.02$) levels of serum OHB compared to dry ewes. Lactating ewes maintained 29% higher ($P \leq 0.005$) serum OHB levels versus the dry ewes.

The concentrations of blood metabolites in the present study differed with values found in the literature. Serum urea exceeded the values reported by Sykes, 1978; 14 - 19 mg/100 ml) and OHB concentrations were lower than values reported for adequately nourished ewes (0.7 mmol/l; Russel *et al.*, 1977). It seemed that no extreme nutrient deficiencies occurred when values in the literature were related to results obtained in this study.

The mean concentrations of NH_3-N and VFA's in the rumen fluid of wethers grazing the pasture together with the ewes are presented in Table 3. Rumen NH_3-N concentrations for both months (22.6 mg/100 ml during April and 16.5 mg/100 ml during June) were also much above 5 mg NH_3-N/100 ml proposed by Roffler & Satter (1975) as the minimum requirement for maximum microbial protein synthesis in the rumen. The values were also in range with the values proposed as optimal for forage intake of forage (20 mg NH_3-N/100 ml; Leng *et al.*, 1993).

The total VFA's were within normal range (6 - 12 mmol/100ml; Ruckebusch & Thivend, 1980). The VFA ratio (acetic:propionic: butyric acid) was also in close agreement with the general ratio of 64:19:17 suggested by Crampton & Lloyd (1959). It therefore seemed that no marked imbalances occurred in terms of VFA concentrations. A low energy content of the pasture would have been reflected in terms of a low proportion of propionic acid in relation to acetic acid in the rumen of sheep (Corbett *et al.*, 1966), due to higher proportions of structural carbohydrates (Ulyatt, 1971).

Conclusions

Dry-land lucerne pasture was adequate for pregnant ewes but deficient in DOM and CP for lactating ewes under this grazing conditions and pasture management scheme. Although ewes may be allowed to deplete body reserves to a certain extent during lactation (Russel, 1984), moderate supplementary feeding of both CP and energy would probably enhance performance of the ewes and their lambs. Blood metabolite concentrations exceeded the values for adequately nourished ewes proposed by other researchers. Rumen NH_3-N concentrations were in excess of the amount needed to satisfy microbial protein synthesis, and in range with the amounts needed for optimal digestibility and intake. Total VFA consentrations were also within normal range. Once the supply of ruminal fermentable N is assured (rumen NH_3-N > 150 mg/l) and adequate digestible energy is provided the next limitation to animal productivity will be the availability of amino acids absorbed from the intestines (Preston, 1986). Therefore, if the animals are not

Table 3 The mean (± SE) concentrations of ammonia nitrogen and volatile fatty acids in the rumen fluid of wethers grazing dry-land lucerne pasture during April and June together with ewes in a six-week rotational system at a stocking rate of 6 ewes/ha.

Rumen parameter	Period	
	April	June
Rumen ammonia nitrogen (mg/100 ml)	22.56±2.05	16.51±0.70
Volatile fatty acids (mmol/100 ml):		
Acetic acid	6.38±0.45	6.42±0.45
Propionic acid	1.66±0.24	1.70±0.23
N-butyric acid	1.09±0.10	0.91±0.06
Isobutyric acid	0.12±0.02	0.08±0.02
Isovaleric acid	0.10±0.02	0.01±0.01
Total VFA's	9.36±0.51	9.12±0.63
VFA ratio %:		
Acetic acid	68.9±3.0	70.6±1.4
Propionic acid	18.1±2.5	18.4±1.9
Butyric acid	13.0±1.0	11.0±0.8

performing to target levels in such a system, bypass protein should be considered.

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Post-Weaning Growth and Carcass Traits of Hair and Wool X Hair Lambs in the US Virgin Islands[1]

R.W. Godfrey [2,3] and J.R. Collins[2]

Summary

Twelve Suffolk x St. Croix White (SFK), 13 Gulf Coast Native x St. Croix White (GCN) and 13 St. Croix White (SCW) lambs were used to evaluate growth and carcass traits of hair and wool x hair lambs under tropical conditions. The lambs were sorted into pens based on sex and sire breed after weaning at 63 days of age. Lambs were allowed to adjust to a concentrate ration for 2 weeks prior to the start of the feeding trial. Lambs were fed a pelleted concentrate ration at 4% of body weight with ad libitum access to guinea grass (Panicum maximum) hay for 100 to 105 days. Average daily gain (ADG) and feed efficiency during the 100-day feeding trial were not different ($P > 0.10$) among the sire breeds. Suffolk sired lambs were heavier ($P < 0.05$) at the end of the feeding trial than SCW lambs, with GCN lambs being intermediate (34.3 ± 1.5 vs 29.8 ±1.2 vs 32.1 ± 1.2 kg, respectively). The cost of total weight gained was highest ($P < 0.05$) for SFK lambs and lowest for SCW lambs (53.18 ± 4.65 vs 39.39 ± 4.03 $US, respectively).

Cold carcass weight was higher ($P < 0.05$) in SFK and GCN lambs than in SCW lambs (17.3 ± 0.9 vs 16.6 ± 0.7 vs 14.9 ± 0.8 kg, respectively). There was no difference ($P > 0.10$) in percent kidney and pelvic fat or rib eye area among the 3 breed types of lambs. The SCW lambs had less ($P < 0.05$) fat over the 12th rib than either the SFK or GCN lambs (0.26 ± 0.04 vs 0.33 ± 0.05 vs 0.37 ± 0.04 cm, respectively). Dressing percent was not affected by breed of sire ($P > .010$). The net value of the carcasses of SFK lambs was lower ($P < 0.05$) than for SCW lambs (5.82 ± 4.85 vs 14.94 ± 3.87 $US, respectively). Crosses of wool and hair sheep can produce larger lambs which in turn yield larger carcasses but the net profit was lower for the larger SFK lambs. Therefore, alternate feeding systems need to be investigated.

Key words: sheep, crossbreeding, carcass quality

Introduction

Although hair sheep make up a small portion of the world sheep population (Shelton, 1991), they are the predominant breed type of sheep found throughout the Caribbean and other tropical regions. Many of the breeds of hair sheep found in the Caribbean can be traced back to African seed stock (Shelton, 1991). Breeds of hair sheep are used worldwide in tropical areas to produce meat (Iriguez et al., 1991; Lallo et al., 1991; Mahieu, 1991; Massiah, 1991; Rastogi et al., 1991; Swartz and Hunte, 1991). Carcass weight of hair sheep lambs raised under a variety of conditions ranges from 4.6 to 18.1 kg (Martinez et al., 1991; Wildeus and Fugle, 1991; Hammond and Wildeus, 1993). However, when hair sheep were crossed with wool sheep, carcass weight of the crossbred lambs was 6 kg heavier than the straightbred hair sheep (McClure et al., 1991). In addition to the enhanced carcass size of hair X wool crossbred lambs, the lipid composition of hair sheep carcasses has a more favorable ratio of saturated to nonsaturated fatty acids (Solomon et al., 1991).

The previous study by McClure et al. (1991) was conducted in a temperate climate. Crossbreeding hair sheep with a large-frame wool breed under tropical conditions has not been evaluated. The flock at the Sheep Research Facility of

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Table 1. Number of crossbred (wool X hair) and purebred (hair) lambs by sex and breed type during the 100 day feeding trial.

	Breed of sire		
	Suffolk	Gulf Coast Native	St. Croix White
Start of feeding trial			
Wethers	5	7	5
Ewes	7	6	8
End of feeding trial			
Wethers	2	5	4
Ewes	7	6	8
Death losses or no carcass data collected			
Wethers	3	2	1
Ewes	2	1	1

UVI consists of St. Croix White and Barbados Blackbelly hair sheep. There are also a small number of Gulf Coast Native wool sheep and 2 Suffolk rams. The objectives of this study were to compare post-weaning growth and carcass traits between St. Croix White (also known as Virgin Island White) and wool X St. Croix White lambs fed a concentrate ration in a tropical environment.

Materials and Methods

St Croix White (SCW) hair ewes were bred to Suffolk and Gulf Coast Native wool and St. Croix White hair rams to produce Suffolk X SCW (SFK), Gulf Coast Native X SCW (GCN) and SCW lambs. Suffolk (large frame) and Gulf Coast Native (medium frame) were selected as sire breeds in order to capitalize on the size differences among the breeds. The Gulf Coast Native rams were from the small flock (12 ewes and 3 rams) at the Sheep Research Facility at UVI, and the Suffolk rams were imported from North Carolina, USA. Mature weights of St. Croix White and Gulf Coast Native rams at UVI averages 65 and 55 kg, respectively. The Suffolk rams weighed 45 kg at 8 mo of age when they were used to breed SCW ewes.

A group of 38 lambs consisting of 12 SFK, 13 GCN and 13 SCW lambs were weaned in groups at an average age of 63 days. For 2 weeks after weaning, lambs were allowed to adjust to a commercial pelleted ration (Caribe Feeds, Granossa Corporation, Bayamon, Puerto Rico; 19% crude protein) and coastal bermuda grass hay. At the end of the 2-week adjustment period the lambs were allotted by sex and sire breed (Table 1) to 6 pens (3.1 X 6.1 meters). Lambs were fed the pelleted feed at 4% of body weight and had ad libitum access to coastal bermuda grass hay and water for 100 to 105 days. Feed and hay refusals from each pen were weighed daily. The lambs were weighed weekly, and the amount of feed offered was adjusted accordingly. Weight gain was determined as the difference between body weight at the start and end of the feeding period. Average daily gain (ADG) was calculated as gain/days on feed. Feed efficiency was calculated per pen as the amount of gain per kg of pelleted feed consumed. Cost of gain (US \$) was calculated based upon the cost of feed (US \$ 0.39/kg), amount of weight gained and feed efficiency using the formula (gain/ feed efficiency) x \$ 0.39.

At the end of the feeding trial the lambs were weighed one day prior to being slaugbtered at the local abattoir. Cold carcass weight, rib eye area measured between the 12th and 13th rib, fat thickness over the 12th rib, percent kidney and pelvic fat (based on cold carcass weight) and hide weight, which included the fleece, were recorded. Dressing percent was calculated as (cold carcass weight , live weight) x 100. Gross carcass value was calculated as (cold carcass weight x \$3.64 US/kg), which was their value on the local market. Net carcass value was calculated as (gross carcass value - cost of gain).

Data were analyzed using General Linear Model procedures (SAS, 1996). Body weight during the feeding period was analyzed using repeated measures procedures. The model consisted of breed, sex, days on feed and the appropriate interactions. Carcass traits were analyzed using breed and sex in the model. All data are reported as least squares means ± SEM.

Results

During the 100 day feeding trial 6 lambs died (Table 1). The causes of death included dog predation, copper toxicity and urinary calculi. An additional 4 lambs did not have carcass data collected due to the closing of the abattoir during 2 hurricanes (Luis and Marilyn) in tbe USVI. Lambs that died during the feeding trial were not included in the analysis of the growth data.

At the start of the feeding trial the SFK lambs weighed more ($P < 0.0001$) than the GCN or SCW lambs (22.2 ± .5 vs 18.4 ± .5 vs 16.7 ± .5 kg, respectively). Even though the rate of growth was similar among the sire breed groups, the SFK lambs were heavier ($P < 0.0001$) than either the GCN or SCW lambs throughout the entire feeding trial (Figure 1). Wethers had similar (P > 0.10) weights as ewe lambs during the feeding trial. The SFK lambs reached 30 kg sooner (P < 0.0006) than either the GCN or SCW lambs (38.5 ± 6.3 vs 67.2 ± 5.0 vs 77.5 ± 5.5 days on feed, respectively). One GCN and 3 SCW lambs never attained a weight of 30 kg during the 105 day feeding period. Total weight gain, ADG and feed efficiency of lambs during the feeding trial were not different (P > 0.10) among sire breeds (Table 2). The SFK lambs had a 35 % higher (P < 0.05) cost of gain than SCW lambs.

There was no difference (P > 0,10) between wethers and ewes in any of the growth or carcass traits measured (Table 2). Suffolk sired lambs were heavier (P < 0.05) at slaughter than SCW lambs, with GCN lambs being intermediate (Table 2). Wool sired lambs had heavier (P < 0.05) cold carcass weight than SCW lambs (Table 2). The hide weight was greatest (P < 0.02) in the SFK lambs and lowest in the SCW lambs. There was no difference (P > 0.10) in rib eye area or kidney and pelvic fat among the 3 breed types of lambs (Table 2). The SCW lambs had less (P < 0.05) fat over the 12th rib than either the SFK or GCN lambs (Table 2). Dressing percent was not affected by breed of sire (P > .10). The gross carcass value was higher (P < 0.05) for the wool sired lambs than for the SCW lambs. Net carcass value was lower (P < 0.05) for SFK lambs than for either GCN or SCW lambs (Table 2).

Discussion

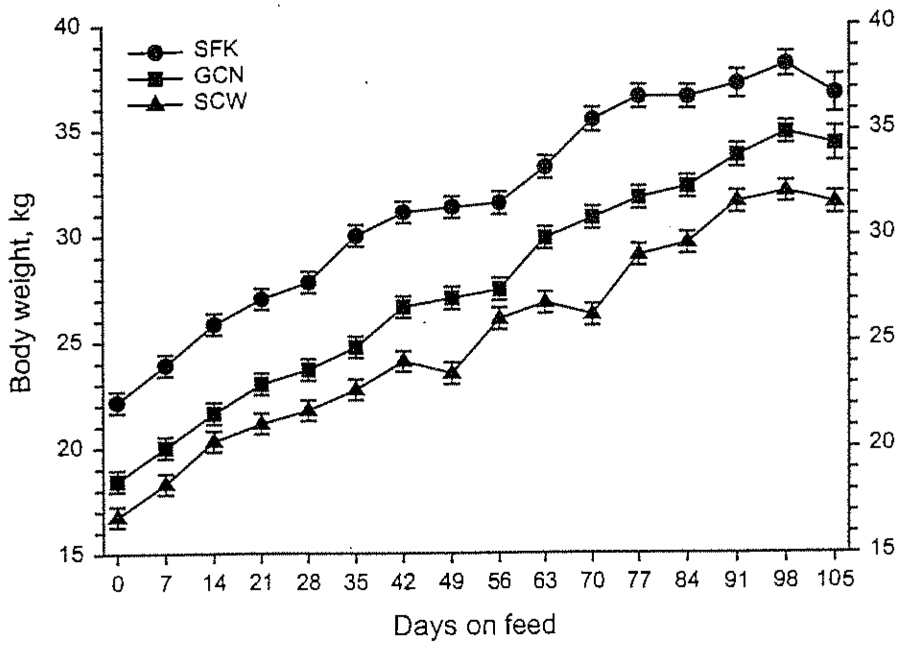
There is very little data available regarding the growth of wool X hair sheep in the tropics. Gatenby et al. (1997) described the neonatal and pre-weaning growth of hair and wool crossbred lambs under tropical conditions, but there was no data presented on post-weaning growth or carcass traits of these sheep. McClure et al. (1991) used a composite breed of sheep that consisted of 1/4 to 1/2 hair (Barbados Blackbelly or St. Croix) and 3/4 to 1/2 wool (Finn x Dorset X Rambouillet). In their study, McClure et al. (1991) reported that the lambs sired by wool rams bred to the composite ewes

Table 2. Growth and carcass traits of lambs sired by Suffolk, Gulf Coast Native or St. Croix White rams bred to St. Croix White ewes after a 100 day feeding trial.

	Sire Breed[a]			Sex of lamb[a]	
Trait	Suffolk	Gulf Coast Native	St. Croix White	Ewe	Wether
Gain, kg	15.9 ± 1.6	16.1 ± 1.2	15.1 ± 1.2	14.9 ±.0.9	16.4 ± 1.3
ADG, g/d	159.5 ± 15.9	157.3 ± 11.8	144.0 ± 11.9	146.3 ± 8.4	161.9 ± 12.4
Feed efficiency, g gain/kg feed	104.7 ± 32.3	124.9 ± 31.2	150.9 ± 32.2	127.8 ± 25.8	125.9 ± 26.4
Cost of gain, US $	53.18 ± 4.65[b]	49.56 ± 4.21[bc]	39.39 ± 4.03[c]	44.80 ± 3.22	50.52 ± 4.44
Live weight, kg	34.3 ± 1.5[b]	32.1 ± 1.2[bc]	29.8 ± 1.2[c]	31.5 ± 0.8	32.9 ± 1.1
Cold carcass wt, kg	17.3 ± 0.9[b]	16.6 ± 0.7[b]	14.9 ± 0.8[c]	15.9 ± 0.5	16.5 ± 0.7
Hide weight, kg	4.3 ± 0.3[d]	3.5 ± 0.2[e]	3.0 ± 0.2[f]	3.5 ± 0.1	3.9 ± 0.2
Kidney and pelvic fat, %	4.2 ± 0.6	5.2 ± 0.5	5.7 ± 0.5	5.3 ± 0.3	4.6 ± 0.5
Rib eye area, cm^2	10.7 ± 0.8	10.9 ± 0.6	10.5 ± 0.6	10.7 ± 0.5	10.9 ± 0.6
Fat thickness, cm	0.33 ± .05[b]	0.37 ± 0.04[b]	0.26 ± 0.04[c]	0.33 ± 0.03	0.35 ± 0.04
Dressing %	50.6 ± 1.1	51.5 ± 0.9	49.9 ± 0.9	50.6 ± 0.7	50.2 ± 0.9
Carcass value, US $	62.19 ± 2.72[b]	60.13 ± 2.28[b]	54.34 ± 2.18[c]	57.59 ± 1.89	59.56 ± 2.36
Net value, US $	5.82 ± 4.85[b]	10.59 ± 4.06[c]	14.94 ± 3.87[c]	12.44 ± 3.16	9.05 ± 3.93

[a]Number of animals is shown in Table 1 as "End of feeding trial".
[b,c]Means with different superscripts are different (P < 0.05).
[c,d,e,f]Means with different superscripts are different (P < 0.02)

Figure 1. Body weight of Suffolk x St. Croix White (SFK), Gulf Coast Native x St. Croix White (GCN) or St. Croix White (SCW) lambs during a 100 to 105-day feeding trial. The SFK lambs were heavier (P < 0.0001) than either the GCN or SCW lambs.



had higher ADG than the straightbred composite lambs.

The ADG of the SCW lambs in the present study (144 g/day) is only slightly higher than that reported by Hammond and Wildeus (1993) for hair sheep lambs fed green chopped guinea grass and a coconut meal supplement (133.3 g/day). In a second trial by Hammond and Wildeus (1993) where molasses was added to the feed, an ADG of 142.0 g/day was achieved. Martinez et al. (1991) reported that hair sheep lambs fed a low quality hay (4.9 % crude protein) supplemented with a concentrate containing 17.1 % crude protein gained 10 kg during a 123-day feeding trial, which translates to an ADG of 81.3 g/day. The pelleted feed used in the present study is produced in Puerto Rico and is the only locally available concentrate feedstuff for small ruminants. The feed tag indicated that the feed contained 14 % crude protein but lab analysis yielded a value of 19 % crude protein on an as fed basis (Dairy One, DHI Forage Testing Laboratory, Ithaca, New York). The higher than indicated crude protein level in this feed may explain why the lambs achieved a higher ADG than that reported by Martinez et al. (1991). The authors did not indicate the level of concentrate feeding, so it is not possible to accurately determine the cause of the difference in ADG between the studies. The similarity between the results in the present study and those of Hammond and Wildeus (1993) may be due to the fact that both studies were conducted at the same facility, using similar procedures and management practices, even though rations were different.

There was no difference detected in feed efficiency among the breed types of lambs, but this may he due to the large amount of variation within each group, as evidenced by the large standard errors (Table 2). The feed efficiency is similar to that reported by Hammond and Wildeus (1993) for lambs fed a coconut meal supplement along with green chopped guinea grass. The higher cost of gain of the SFK lambs is in part due to their lower feed efficiency, since there was no difference in the amount of weight gained among the breed groups (Tahle 2). The relatively high cost of gain of SFK and GCN lambs indicates wool crosses are not desirable in a concentrate feeding system under tropical conditions.

There were very few differences in the carcass traits among the breed types of lambs in the present study (Table 2). The SFK and GCN lambs yielded larger carcasses than the SCW lambs, but there was no difference in rib eye area, percent kidney and pelvic fat, or dressing percent. The SCW lambs had less fat cover than the wool sired lambs, which is in agreement with Hammond and Wildeus (1993), and McClure et al. (1991). McClure et al. (1991) noted that hair sheep lambs are leaner than wool lambs and deposit less fat externally. Subjective observations in our laboratory have indicated that SCW lambs tend to store more fat in the body cavity than as fat over the ribs and loin. This pattern is found in the present study where the SCW lambs tended to have a higher percent kidney and pelvic fat than the SFK lambs. The leanness of SCW lambs may be a useful marketing tool in the present marketplace where the consumer is interested in purchasing leaner cuts of meat for health reasons.

The low net value of SFK lambs in comparison to the GCN and SCW lambs is related to the cost of gain and feed efficiency (Table 2). Because the SFK lambs had a lower financial return than the SCW or GCN lambs, it may not be feasible to utilize the larger SFK lambs in a concentrate feeding system. Initially it would appear from the larger size of the SFK lambs they would produce a larger carcass, which they did, and in turn yield a higher carcass value for the producer. However, because of their lower feed efficiency, higher feed costs more than offset any benefit the larger carcass produced.

Conclusions

Because the crossbred lambs, sired by Suffolk rams, were heavier than the straightbred hair lambs the potential exists for an increase in meat production. Suffolk sired lambs were heavier than the straightbred hair lambs throughout the feeding period, while the Gulf Coast Native sired lambs were closer in weight to the St. Croix White sired lambs. This is most likely due to the fact that Gulf Coast Native sheep do not achieve a similar mature size of the larger Suffolk breed. This weight advantage of Suffolk sired lambs would allow them to be marketed at a younger age and still produce a heavier carcass than straightbred hair lambs of the same age. The higher cost of gain for the Suffolk sired lambs may limit their use under tropical management conditions. The net value of Suffolk sired lamb carcasses was $5.82 and the St. Croix White carcasses had a net value of $14.57. This difference is explained by the lower feed efficiency of the Suffolk sired lambs. Further studies need to be conducted to determine if the heavier body weight of the crossbred lambs will be maintained when the lambs are raised on native pastures, instead of being provided with concentrate. By crossbreeding native hair sheep with wool breeds it may be possible for sheep producers in the Caribbean to increase meat production. As a precaution, wool rams should be limited to use as terminal sires in production systems that are raising lambs for meat and not for breeding stock. This is critical to maintain the purity of the germplasm of the hair sheep breeds in the Caribbean.

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News and Notes

Request for Original Papers

The E (Kika) de la Garza Institute for Goat Research has been awarded a grant from the United States Department of Agriculture for a project to update the nutrient requirement of goats. It is our goal to produce a publication to reflect the diversity of animal and systems under which they are managed. Although we have access to most of the information published in the U.S. and Canada, we feel very strongly that this revision should encompass the body of knowledge on goat nutrition throughout the world. To that end, we are requesting assistance. We would greatly appreciate the contribution of original research papers from various regions in order to construct a database from which requirements for different classes of animals may be generated. Those interested in participating, please contact: Amey L. Adams, E (Kika) de la Garza Institute for Goat Research, P.O. Box 730, Langston University, Langston, OK 73050, or e-mail aadams@mail.luresext.edu.

Area Code Change

The area code for the Sheep & Goat Research Journal has changed from 502 to 270. The change goes into effect immediately. The new area code and phone/ fax number is (270) 782-8370.

Potential Veterinary Medical Officer or Analytical Epidemiologist Job Opening with USDA:APHIS:VS Centers for Epidemiology and Animal Health

The USDA, Animal and Plant Health Inspection Service, Veterinary Services, Center for Epidemiology and Animal Health (CEAH) in Fort Collins, Colorado, anticipates recruiting for an Analytical Epidemiologist or Veterinary Medical Officer to serve as a Sheep Commodity Specialist.

The specialist will provide knowledge of sheep health and leadership in conducting epidemiologic studies and analysis for CEAH's National Animal Health Monitoring System (NAHMS). Specific duties include: (1) assessment of sheep industry animal health information needs and collection of appropriate data; (2) development of research hypotheses, analytical models, and study design; (3) analysis and reporting of results to Federal/State, industry, and technical audiences; and (4) enhance and maintain working relationships between sheep industry groups and NAHMS. The first ever national on-farm study of the US sheep industry through NAHMS is being planned for 2001 and the sheep specialist will be an integral part of the team behind this effort.

To express your interest in this type of position, please mail a CV to Dr. Nora Wineland, USDA: APHIS:VS, 555 S. Howes, Fort Collins, CO 80521. You may also contact her by phone at (970) 490-7937. If and when the position is formally announced, a copy of the vacancy announcement will be mailed to you and you will be required to apply for the position. A CV sent to Dr. Wineland will not be considered an application only a show of interest in the position. U.S. Citizenship is required.

Check the federal job website at www.usajobs.opm.gov. New postings are added every Monday.

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Sheep & Goat Research Journal

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Objective

The aim of the Sheep & Goat Research Journal is to provide a peer-reviewed scientific publication of sheep and goat research findings which can be used by scientists, educators, veterinarians, extension agents and producers alike. The Journal is published three times each year by the Livestock Conservation Institute, in cooperation with the American Sheep Industry Association.

Editorial Policy

The Sheep & Goat Research Journal publishes 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 articles must represent unpublished original research, and conclusions reached must be supported by research results. Articles that promote commercial products or services will not be approved for publication. Articles that promote practical applied research are encouraged. The submission of review articles is accepted but will require the same review process as other submitted articles. At least one author of each submitted article must subscribe to the Journal. All manuscripts and correspondence should be addressed to Sheep & Goat Research Journal, P.O. Box 51267, Bowling Green, KY 42102-5567. Inquiries may be sent via electronic mail to sheep2goat@aol.com.

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Manuscripts will be subject to critical review by an editorial board or others designated by the editor. Authors will be notified by mail of acceptance or rejection of papers. Manuscripts needing revision will be returned to the corresponding author and should be revised and returned by the deadline indicated. Papers not suitable for publication will be returned to the corresponding author with a statement of reason for rejection. Consult the Sheep & Goat Research Journal *Editorial Policies and Procedures* for details of the technical requirements for manuscripts submitted to the Journal.

Manuscript Submission

Manuscripts should be mailed to the Sheep & Goat Research Journal, P.O. Box 51267, Bowling Green, KY 42102-5567. Five copies of each manuscript must be submitted. Each manuscript must be accompanied by a cover letter from the main corresponding author. The cover letter must include the mailing address, telephone and fax numbers, and e-mail address of the corresponding author. As a style reference, authors may refer to the Publication Manual of the American Physiological Association. Every effort is made to publish papers promptly. Normally, a paper is published approximately six months after it is received from the authors.

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Manuscripts must be typed and double-spaced. 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. When papers are accepted for publication, the authors must send a floppy disk with the manuscript in Microsoft Word format with two hard copies. Submission of excessive tabular data is discouraged; tables should be limited to that data that is considered essential to the research findings. Tables must be typed, double-spaced, and placed 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.

Please contact the Sheep & Goat Research Journal office to obtain a copy of the Journal's *Editorial Policies & Procedures* document for detailed formatting instructions.

The following format should be used when submitting research manuscripts:

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**

When 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." Please provide "interpretive summaries" for use by the sheep and goat industries in other media.

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

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Volume 15, Number 1:

Volume 15, Number 2:

Ewe Reproductive Performance and Lamb Preweaning Growth and Survival in Finnsheep Crossbred Ewes Lambing in Spring or Fall[1]

Bee Tolman[2] and David R. Notter[3]

Summary

Reproduction and maternal performance of ½-Suffolk, ¼-Rambouillet, ¼-Finnsheep (1/4-Finn) and ¼-Suffolk, ¼-Hampshire, ½-Rambouillet (Western) adult ewes were compared over 3 yr in spring (March and April) and fall (September and October) lambing. Fertility was higher ($P < .001$) in spring (93.4%) compared to fall lambing (63.9%). The ¼-Finn ewes were slightly more fertile than Western ewes in fall lambing (68.5 versus 59.3%) but not in spring lambing (94.2 versus 92.5%). Prolificacy (number of lambs born per ewe lambing) was higher ($P < .001$) in spring than fall and was higher ($P < .001$) for ¼-Finn ewes than for Western ewes (2.23 versus 1.86 in spring and 1.72 versus 1.41 in fall). The ¼-Finn ewes also lambed an average of 7 d earlier in fall but only 2 d earlier in spring. Birth weights (unadjusted for litter size) were less for lambs from ¼-Finn ewes in spring (4.3 versus 3.9 kg) but not in fall (4.1 kg for both ewe types). After adjustment for birth type, lambs from ¼-Finn ewes remained .2 ± .1 kg lighter at birth in spring but averaged .2 ± .2 kg heavier at birth in fall. Lamb survival to 30 d was slightly higher ($P < .10$) in spring (90%) than fall (82%) but did not differ between ewe types. Preweaning daily gains were calculated at about 55 d in both seasons and at weaning at 90 d in spring and 70 d in fall. At 55 d, gains did not differ between lambs from ¼-Finn (302 g/d) and Western ewes (293 g/d). Gains to weaning were likewise similar for lambs from ¼-Finn (284 g/d) and Western ewes (280 g/d). Results of this study confirm that use of ¼-Finn ewes can enhance reproductive efficiency without negative effects on lamb performance to weaning.

Key words: sheep, breeds, reproduction, fertility, growth

Introduction

The management structure of a commercial sheep production enterprise is often determined by availability of resources such as forages, facilities, and labor. The choice of ewe breed type and season of lambing affects use of those resources as well as the resulting production and profitability of the operation. In Virginia, "Western" ewes produced by crossing Rambouillet ewes to blackfaced Suffolk or Hampshire rams are a popular crossbred type, well suited to spring-lambing, pasture-based production systems. More recently, many producers have incorporated Finnsheep breeding into their flocks (Dickerson, 1977; Oltenacu and Boylan, 1981a,b; Ercanbrack and Knight, 1988; Fahmy, 1989; Notter and McClaugherty, 1991). However, despite evidence (Notter et al., 1991) that lambs from ¼-Finnsheep ewes are equal to those from ewes without Finnsheep breeding in growth and carcass composition, some biases against the perceived inferior performance of lambs from Finn-cross ewes remain.

Fall lambing may offset some disadvantages of spring-lambing systems such as summer heat, predation, parasites, and low autumn lamb prices. However, fall lambing systems are often constrained by reduced reproductive performance, as both fertility and litter size per ewe lambing are substantially below that anticipated in spring lambing (Barr et al., 1968; Notter and Copenhaver, 1980a; Fogarty et al., 1984; Notter, 1992). Production differences between spring and fall lambing may be reduced through the use of ewe breeds that have higher out-of-season conception rates and (or) higher prolificacy in fall lambing.

This study was designed to compare production to weaning of two ewe breed

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types in two annual lambing seasons. Western and ¼-Finn ewes were bred to Suffolk x Hampshire rams to lamb in March or September. Characteristics evaluated were percentage of ewes that lambed, lambing date, litter size, lamb birth weight, lamb survival, and lamb daily gain to weaning.

Materials and Methods

Populations and Experimental Design

This 3-yr experiment, conducted at the Southwest Virginia Agricultural Research and Extension Center in Glade Spring, compared the performance of ¼-Suffolk, ¼-Hampshire, ½-Rambouillet (Western) and ½-Suffolk, ¼-Rambouillet, ¼-Finnsheep (1/4-Finn) ewes. Ewes were 4 or 5 yr old at the start of the trial. The origin and previous performance of these ewes in a somewhat different set of lambing seasons were described by Notter and McClaugherty (1991).

Ewes were divided into two breeding groups, one bred in the fall to lamb in spring and the other bred in the spring to lamb in fall. Numbers of ewes and breeding dates are shown in Table 1. All ewes were bred to Suffolk x Hampshire rams throughout the study. No culling was performed on the basis of performance; removal of ewes from the flock was due only to unsoundness or death.

Animal Management

Spring-lambing ewes were exposed to rams in a single group. Mating began in the first week of October and continued for 90 d in yr 1 and 60 d in yr 2 and 3 (Table 1). During breeding, ewes were maintained on perennial, cool-season pastures containing primarily orchardgrass (Dactylis glomerata), Kentucky bluegrass (Poa pratensis), and white clover (Trifolium repens). Ewes then grazed stockpiled fescue (Festuca arundinacea) until January and were fed hay while on pasture through mid-winter until lambing. In the last 6 wk of gestation, ewes were supplemented with .35 $kg \cdot head^{-1} \cdot d^{-1}$ of corn. Lambing took place in drylot; ewes were fed hay and .7 $kg \cdot head^{-1} \cdot d^{-1}$ of corn after parturition.

Ewes and lambs were moved to winter rye (Secale cereale) pastures in mid-March, at which point corn supplementation ceased. Lambs were given access to creep feed while ewes grazed rye. Ewes and lambs were moved to perennial pastures as they became available in mid-April; creep feeding of lambs was discontinued at this time. In yr 1 and 2, ewes and lambs were continuously stocked on perennial pasture from mid-April to early June; in yr 3 they were rotated through .4-ha paddocks of improved pasture at approximately weekly intervals. Lambs

Table 1. Dates of breeding, lambing, weighing, and weaning for spring and fall lambing

Lambing season	Activity	Dates in: Year 1	Year 2	Year 3
Spring	Breeding	October 1-December 30	October 1-November 30	October 6-November 24
	(No. ewes exposed)[a]	(29 W, 35 F)	(28 W, 30 F)	(26 W, 25 F)
	Lambing	February 22-May 11	February 8-April 9	February 24-April 15
	(Mean lambing date)	(March 6)	(March 5)	(March 9)
	First weighing	[b]	May 7	April 29
	(Avg. age, d)		(65)	(52)
	Weaning	June 5	June 11	May 29
	(Avg. age, d)	(92)	(98)	(81)
Fall	Breeding	April 4-June3	April 7-June 6	March 31-May 2
	(No. ewes exposed)[a]	(27 W, 28 F)	(26 W, 31 F)	(26 W, 27 F)
	Lambing	August 26-October 26	September 1-October 17	August 25-October 14
	(Mean lambing date)	(September 18)	(September 15)	(September 5)
	First weighing	November 8	November 12	October 27
	(Avg. age, d)	(52)	(63)	(55)
	Weaning	December 2	November 21	November 16
	(Avg. age, d)	(74)	(66)	(71)

[a]W = Western and F = ¼-Finn ewes. [b]Lambs were not weighed before weaning in year 1.

were weighed at average ages of approximately 57 and 90 d (Table 1).

Fall lambing ewes were exposed to rams in a single group for 60 d beginning the first week of April (Table 1). Beginning on about February 1 of each year, rams to be used in spring breeding were placed in a darkened section of a bank barn at about 1400 each day to provide short-day light cycles typical of those experienced in fall breeding. Rams were removed from the darkened barn after sunset each day. Light treatments continued until the start of breeding. Ewes were flushed with .25 $kg \cdot head^{-1} \cdot d^{-1}$ of corn from March 10 to April 15. Ewes were maintained on pasture throughout gestation; no supplement was provided during gestation or lactation.

In late August, ewes were moved to alfalfa pastures for lambing. In yr 1 and 2, ewes remained on alfalfa until turnip grazing was available in mid-October (Tolman, 1993). Lambs were weaned in late November after turnips were depleted. In yr 3, ewes and lambs remained on alfalfa pastures throughout lactation until weaning. Lambs in yr 1 and 2 did not have access to creep until ewes were moved to turnips. Lambs in yr 3 were given access to creep throughout lactation. Lambs were weighed at approximately 56 d and again at weaning at approximately 70 d of age (Table 1). At weaning, lambs were moved directly to drylot and ewes were put on stockpiled fescue pastures for winter grazing.

Components of ewe reproductive efficiency that were monitored included ewe fertility, prolificacy and lambing date, and lamb birth weight, survival from birth to 30 d, and preweaning daily gain. Fertility was defined as the percentage of ewes exposed that lambed. Prolificacy was defined as the average number of lambs born per ewe lambing. Lambing dates were expressed as the number of days from initial ram exposure until lambing. Ewes were given the opportunity to raise all lambs born; grafting occurred only if a ewe's entire litter died at or shortly after birth or if a ewe was clearly not able to suckle her entire litter. Early preweaning daily gain was determined from birth to approximately 55 d of age, except in spring of yr 1, when no weights were taken before weaning. Daily gain was also measured from birth until weaning at approximately 90 d for spring-born lambs and 70 d for fall-born lambs (Table 1).

Statistical Analysis

A 2 x 2 factorial arrangement of treatments was used in this study to evaluate ¼-Finn versus Western crossbred ewe types and spring- versus fall lambing. Ewes within each treatment combination were evaluated over 3 yr to assess ewe productivity, lamb viability, and lamb growth. Chi-square analyses were conducted using the frequency procedure of the Statistical Analysis System (SAS, 1990) to determine significance of ewe breed and season effects on categorical variables (fertility, prolificacy, and lamb survival). Chi-square tests of significance for effects of ewe breed were calculated after controlling for effects of season, and vice versa, using the Cochran-Mantel-Haenszel statistics provided in SAS (1990). In addition, effects of ewe breed and season on survival were evaluated after controlling for litter size. Analysis of variance was conducted using the general linear models procedure of SAS (1990) to evaluate fixed effects of ewe breed, season, year, and their interactions on lambing date (with ewe as the experimental unit) and on lamb birth weight and lamb daily gain to 55 d and to weaning (with lamb as the experimental unit). Analyses were conducted with and without the effect of birth type in the model. Tests of significance were made at $P < .05$.

Results and Discussion

Fertility

Ewe breed had no significant effect on fertility in either spring or fall lambing (Tables 2 and 3). In spring, 94 ± 2% of ¼-Finn ewes and 93 ± 3% of Western ewes lambed. In fall, 69 ± 7% of ¼-Finn ewes and 59 ± 5% of Western ewes lambed. This nonsignificant breed effect on fer-

Table 2. Least squares means and standard errors for ewe reproductive performance, lamb birth weight and survival, and lamb daily gain to 55 d and to weaning in spring lambing

	Year							
	1		2		3		Combined	
Item	Western	¼-Finn	Western	¼-Finn	Western	¼-Finn	Western	¼-Finn
Fertility, %	96.6 ± 3.4	100.0[a]	96.4 ± 3.5	86.7 ± 6.2	84.6 ± 7.1	96.0 ± 3.9	92.5 ± 2.8	94.2 ± 2.4
Prolificacy	1.75 ± .14	2.34 ± .13	1.78 ± .15	2.15 ± .16	2.05 ± .15	2.21 ± .18	1.86 ± .08	2.23 ± .09
Lambing date, d	157 ± 1	156 ± 1	157 ± 1	154 ± 1	155 ± 1	153 ± 1	156 ± 1	154 ± 1
Birth weight, kg	4.3 ± .1	3.7 ± .1	4.3 ± .2	3.8 ± .1	4.2 ± .2	4.1 ± .1	4.3 ± .1	3.9 ± .1
30-d survival, %	87.8 ± 6.1	89.0 ± 5.3	89.6 ± 5.8	80.4 ± 7.2	93.3 ± 4.9	90.6 ± 5.8	90.2 ± 2.4	86.7 ± 2.4
Daily gain to 55 d, g	b	b	291 ± 9	318 ± 9	268 ± 9	277 ± 9	280 ± 9[c]	298 ± 9[c]
Daily gain to weaning, g	264 ± 9	245 ± 5	259 ± 9	277 ± 9	245 ± 9	255 ± 9	256 ± 5	259 ± 5

[a]Standard errors could not be calculated when fertility = 100%. [b]Lambs were not weighed before weaning in yr 1. [c]Average of yr 2 and 3.

tility agrees with previous studies (Fogarty et al., 1984; Notter and McClaugherty, 1991) but, when combined with differences in prolificacy, may contribute to differences in overall ewe productivity and profitability (Fahmy and Dufour, 1988).

Fertility differed (P < .001) between seasons. Overall fertility was 94% for spring lambing and 64% for fall lambing. Barr et al. (1968) reported that ewes exposed to rams in spring had both a reduced frequency of mating and reduced pregnancy rates among ewes that mated compared to ewes bred in fall. Thus the seasonal difference in fertility in the current study may have been caused by a combination of fewer ewes cycling and reduced embryonic survival after fertilization.

Over the 3 yr of the study, fertility in the fall-lambing group declined by over 25% for both breed groups, while the spring-lambing group showed no clear changes in fertility. This decline in fertility in spring of yr 2 and 3 may have been associated with the substantial weight losses of ewes grazing turnips during lactation in fall of yr 1 and 2 (Tolman, 1993). Fertility in April and May in the current study was substantially lower in all years than the fertility levels of 89 to 90% reported by Notter and McClaugherty (1991) for the same ewes bred in June and July at 3 or 4 yr of age. Acceptable levels of fertility were therefore considerably more difficult to obtain with early-fall (September and October) compared to late-fall (November and December) lambing. Light treatment of rams, which was not used by Notter and McClaugherty (1991), was anticipated to improve ram fertility, and the period of ram confinement was accompanied by limited concentrate feeding of the rams, so ram condition should not have been a problem. Still, no control, untreated males were available to test actual effects of ram light treatments.

Fertility of ewes in spring matings can vary widely among breed types, regions, and management systems. Notter (1992) reviewed genetic differences in traits associated with seasonal breeding. In general, the Dorset, Rambouillet, and Finnsheep, and derived breeds such as the Polypay, appear to be most desirable for use in spring mating, whereas the large blackfaced breeds such as Hampshire and Suffolk are less desirable. Reasonably good performance in spring matings has been achieved with a number of breed types at this location. For additional information, see Notter and Copenhaver (1980a), Nugent et al. (1988a,b), Dzabirski and Notter (1989), and Notter and McClaugherty (1991). Although ewes in the current study were not selected for ability to lamb in fall, Notter et al. (1998) have also demonstrated that selection can also be effective in improving spring fertility.

Prolificacy

Prolificacy was affected by both ewe breed and season (P < .001; Tables 2 and 3). When ewe breeds were combined, mean litter size was 2.06 in spring and 1.58 in fall. Western ewes averaged 1.84 and 1.40 lambs/ewe in spring and fall, respectively; ¼-Finns averaged 2.25 and 1.71 lambs/ewe in spring and fall. Mean litter sizes over the 3 yr (spring and fall lambings combined) were 2.03 for ¼-Finns and 1.68 for Western ewes. One-quarter Finn ewes gave birth in the spring to .59, .37, and .16 more lambs/ewe lambing in yr 1, 2, and 3, respectively, than Western ewes. In fall, ¼-Finn ewes produced .38, .17, and .38 more lambs/ewe than Westerns. These breed effects on prolificacy were similar to those reported by Oltenacu and Boylan (1981a), Fahmy and Dufour (1988), and Notter and McClaugherty (1991).

Over 3 yr of fall lambing, 60% of Western lambings produced singles and no Western ewes produced triplets, whereas 36% of ¼-Finn lambings produced singles and 7% produced triplets. In spring, 66% of Westerns had twins and 9% had triplets, whereas 49% of ¼-Finns had twins and 38% had triplets.

Lambing Date

Mean lambing dates were March 6 and September 13 for spring- and fall-lambing groups, respectively (Table 1). Ewe

Table 3. Least squares means and standard errors for ewe reproductive performance, lamb birth weight and survival, and lamb daily gain to 55 d and to weaning in fall lambing

	Year							
	1		2		3		Combined	
Item	Western	¼-Finn	Western	¼-Finn	Western	¼-Finn	Western	¼-Finn
Fertility, %	74.1 ± 8.4	82.1±7.2	57.7±9.7	67.7±8.4	46.2±9.8	55.6±9.6	59.5±5.5	68.6±5.0
Prolificacy	1.40±.16	1.78±.16	1.40±.18	1.57±.16	1.42±.21	1.80±.21	1.40±.11	1.71±.10
Lambing date, d	169±2	166±2	168±2	157±2	162±2	154±2	166±1	159±1
Birth weight, kg	3.9±.2	3.9±.2	4.3±.2	4.4±.1	4.2±.2	4.0±.2	4.1±.1	4.1±.1
30-d survival, %	82.1±7.4	82.9±7.1	76.2±8.4	93.9±4.3	88.2±6.3	85.2±6.8	82.2±4.7	87.3±3.3
Daily gain to 55 d, g	300±14	291±9	309±14	295±9	314±18	323±18	308±9	303±9
Daily gain to weaning, g	273±14	286±9	305±14	300±9	336±18	345±14	305±9	310±5

breed had a significant effect on birth date. Over the 3 yr, Western ewes lambed an average of 5 ± 2 days later than ¼-Finn ewes; the difference remained (4 ± 1 d) when birth date was adjusted for litter size. However, ewe breed effects were larger in fall (7 ± 2 d) than spring (2 ± 1 d; $P < .05$ for breed x season interaction). The significance of ewe breed x season interaction did not change when lambing date was adjusted for litter size. In contrast, Notter and McClaugherty (1991) observed no ewe breed effect on lambing date for ewes lambing in November and December.

In spring lambing, average lambing dates in yr 1, 2, and 3 were 157, 157, and 156 d, respectively, after first exposure to rams for Western ewes and 156, 153, and 153 d, respectively, after first exposure for ¼-Finn ewes. In fall lambing, the average lambing dates in yr 1, 2, and 3 were 168, 168, and 162 d, respectively, after first exposure to rams for Western ewes, but only 166, 157, and 155 d, respectively, after first exposure for ¼-Finn ewes. These results would suggest that more ¼-Finn ewes were already cycling when exposed to rams, whereas more Western ewes may have been induced to cycle by ram introduction (Nugent et al., 1988a; Oldham and Fisher, 1992).

Birth Weight

Litter size affected birth weight ($P < .05$). Birth weights of single, twin, and triplet lambs were 4.9, 4.0, and 3.5 (± .1) kg, respectively. There were no significant litter size x season or litter size x ewe breed interactions. Ewe breed influenced lamb birth weight, primarily through effects on litter size. Lambs from Western ewes averaged .3 ± .1 kg heavier ($P < .01$) at birth than lambs from ¼-Finn ewes (Tables 2 and 3). This difference was slightly larger than that reported by Notter et al. (1991) for the same Western and ¼-Finn ewes, but was consistent with Maijala's (1984) estimate of a .27% decrease in birth weight with each 1% increase in proportion of Finnsheep genes.

There was virtually no difference in average birth weight of spring- and fall-born lambs. When adjusted for birth type, however, spring lambs were .4 ± .1 kg heavier than fall lambs. Similar trends were reported by Notter and Copenhaver (1980a), and both Barr et al. (1968) and Al-Shorepy and Notter (1998) found significant seasonal effects on birth weight without litter size adjustment.

The interaction between ewe breed and season was significant for birth weight. Lambs from Western ewe were .5 ± .1 kg heavier in spring but only .1 ± .1 kg heavier in fall. When spring birth weights were adjusted for litter size, the breed difference was reduced but remained significant (.2 ± .1 kg). When fall weights were adjusted for litter size, the breed difference was reversed, but was not significant; lambs from ¼-Finn ewes weighed .2 ± .2 kg more than lambs from Western ewes.

Lamb Survival

Survival to 30 d of age, a possible indicator of mothering ability or lamb vigor, was not significantly affected by ewe breed or season and averaged 87% (Tables 2 and 3). There was no difference in survival between ¼-Finn lambs born in fall and spring (87 ± 2 and 87 ± 3%, respectively). However, the seasonal difference in survival of lambs from Western ewes approached significance (90 ± 2% in spring and 82 ± 5% in fall; $P = .09$) and may have been associated with reduced birth weights of fall-born lambs from Western ewes.

Survival to 30 d declined significantly with increasing litter size. Singles, twins, and triplets had survival rates of 93.7, 88.0, and 81.4%, respectively. This pattern is similar to that noted by Oltenacu and Boylan (1981a) in Minnesota. However, Notter et al. (1991) found a curvilinear relationship between perinatal survival and both birth type and birth weight such that survival was maximal for twins and at a birth weight of 4.4 kg.

Daily Gain to 55 d of Age

Lambs were weighed at approximately 55 d of age to determine ewe breed and season effects on early lamb growth. Contrary to results summarized by Maijala (1984), this study found no negative relationship between Finnsheep breeding in lambs and preweaning daily gain. Daily gain did not differ between ewe breed types and averaged 268 g/d from birth to 55 d over the 3 yr (Tables 2 and 3). The slight and nonsignificant advantage in rate of gain in lambs from ¼-Finn versus Western ewes (300 ± 14 versus 295 ± 14 g/d) was similar to that reported by Notter et al. (1991).

Birth type affected early lamb growth ($P < .001$). Over the 3 yr, singles averaged 373 ± 9 g/d, twins averaged 282 ± 5 g/d, and triplets averaged 259 ± 18 g/d. There was no significant ewe breed x birth type interaction for daily gain to 55 d. However, when birth type was included in the model, the effect of Finn breeding on gain to 55 d became significant. At the same birth type, lambs from ¼-Finn ewes gained more than lambs from Western ewes in spring (323 ± 9 versus 300 ± 9 g/d) and fall (300 ± 9 versus 286 ± 14 g/d). These relatively desirable early gains by lambs out of ¼-Finn ewes may have reflected differences in milk production between ewe types or the rapid early maturing rate of Finnsheep crosses. However, as shown by Notter et al. (1991) and Tolman and Notter (1999), offspring of ¼-Finn ewes were not able to maintain higher postweaning rates of gain relative to lambs out of Western ewes. Notter et al. (1991) also reported that lambs from ¼-Finn and Western ewes were essentially identical in age and carcass composition when slaughtered at the same weights.

A seasonal effect on early lamb gain was observed. Gains in spring averaged 291 ± 5 g/d while gains in fall averaged 305 ± 5 g/d ($P < .05$). This effect is difficult to interpret in terms of causal environmental factors. Fall-born lambs in yr 1 and 2 did not have access to creep until mid-October, when they were approximately 30 d of age, while fall-born lambs in yr 3 had continuous access to creep from birth. Spring-born lambs in yr 1 and 2 had access to creep only until approximately 45 d of age, and spring-born lambs in yr 3 had no creep at all. Temperature would not have been extreme in either season during this period. With similar crossbred types given equal creep access in forage-based spring and fall systems, Notter et al. (1991) found no significant seasonal effect on lamb gain before 70 d. However, Notter and Copenhaver (1980b) reported that daily gains of lambs raised on expanded metal (and thus in a controlled environment except for effects of temperature) were greater for April-born lambs than for September-born lambs. These results demonstrate that preweaning gain is heavily influenced by environmental factors, such as temperature, forage quality and availability, and creep feeding. The higher rate of gain in fall, however, may also be due in part to a smaller number of lambs suckling the ewes. Single lambs have more milk available to them and consequently have greater growth during lactation than twins (Barnicoat et al., 1956; Brown, 1964).

Lamb Daily Gain to Weaning

Lambs were weighed at weaning to determine effects of breed type and season on overall preweaning lamb growth. Ewe breed did not have a significant effect on lamb growth to weaning. Lambs from ¼-Finn and Western ewes gained 286 ± 5 g/d and 282 ± 5 g/d, respectively (Tables 2 and 3). When birth type was included in the model, ewe breed effects were significant. Lambs from ¼-Finn ewes gained 18 ± 9 g/d faster from birth to weaning than did lambs from Western ewes.

Effects of birth type remained significant for daily gain to weaning. Single, twin, and triplet lambs gained an average of 332 ± 5, 268 ± 5, and 245 ± 9 g/d, respectively. No significant breed x birth type or season x birth type interactions for daily gain to weaning were found.

Season also affected lamb gain to weaning ($P < .001$). Lambs in spring gained 259 ± 5 g/d, whereas lambs in fall gained 309 ± 5 g/d. The difference in gain between spring and fall seasons increased from 18 ± 9 g/d at 55 d of age to 50 ± 5 g/d at weaning. This increase reflects differences in management and environment after 55 d. Fall lambs had continued access to creep feed and gained at similar rates before and after 55 d. In contrast, spring lambs were not creep fed after 55 d and their gains declined. Also, spring lambs averaged 55 d of age in late April and early May when ambient air temperature and parasite exposure on pasture would have been increasing. Fall lambs averaged 55 d of age in late October and early November while grazing turnips or alfalfa; cooler temperatures and reduced parasite exposure would have encouraged higher daily gains. There was no significant ewe breed x season interaction.

Conclusions

Fertility of crossbred ewes exposed in April and May was lower than that of the same ewes exposed in June and July. The addition of ¼-Finn breeding to the crossbred ewe type increased reproductive efficiency by slightly increasing fertility in fall and significantly increasing prolificacy in both spring and fall. The larger litter sizes and resultant lighter birth weights of lambs from ¼-Finn ewes had no subsequent effect on lamb viability or growth; there were no differences between breed groups in lamb survival or rates of gain.

Fall lambing reduced the reproductive efficiency of both ewe breeds. However, ¼-Finn ewes were more productive than Western ewes in fall lambing. More ¼-Finn ewes appeared to be cycling at April breeding, and ¼-Finn ewes had larger litters in fall. Fall-born lambs out of Western ewes had reduced birth weights and survival. Lamb daily gain to weaning was greater in fall than in spring, presumably reflecting a combination of factors, such as smaller litter sizes, cooler temperatures, and more access to creep.

The success of any production system largely depends on the quantity of marketable product produced from a given set of resources. Improving reproductive efficiency with more prolific breeds increases overall weight of lamb weaned/ewe. The benefits of greater lamb numbers per ewe exposed must then be weighed against the demands of larger litter sizes on management and other resources. Use of a prolific breed, such as the Finnsheep, may, however, be essential for improved reproductive efficiency in fall-lambing systems.

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Effects of Ewe Breed Type, Season, and Weaning Age on Postweaning Performance of Crossbred Lambs[1]

Bee Tolman[2] and David R. Notter[3]

Summary

In each of 3 yr, progeny of ½-Suffolk, ¼-Rambouillet, ¼-Finnsheep (¼-Finn) and ¼-Suffolk, ¼-Hampshire, ½-Rambouillet (Western) ewes were compared for postweaning daily gain and age and weight at marketing in spring and fall lambing. In addition, spring lambs were either weaned to medium-quality perennial cool-season pastures at about 90 d of age in early June or remained with their dams on comparable pastures during the summer. Progeny of Western ewes grew slightly faster than progeny of ¼-Finn ewes on summer pastures (155 ± 5 versus 145 ± 5 g/d) but did not differ in mean weight (47.1 kg) or age (205 d) at marketing. Fall lambs were fed in drylot after weaning at about 70 d. Fall lambs from Western ewes grew somewhat faster postweaning (280 ± 8 versus 262 ± 6 g/d; $P < .10$) but did not differ from lambs from ¼-Finn ewes in market weight (50.0 ± .4 kg) or age (164 ± 2 d). Spring lambs that remained with their dams during summer gained more than weaned lambs (189 ± 5 versus 109 ± 5 g/d; $P < .001$). This relatively large effect of weaning presumably reflected the modest summer forage quality and high levels of internal parasite infestation experienced during the study. Weaned lambs correspondingly averaged 18 ± 3d older and 2.5 ± .5 kg lighter at marketing. These results suggest that spring lambs should be left with their dams during the summer grazing period unless very high quality forage is available and internal parasites are rigorously controlled.

Key words: sheep, growth, weaning age, forages, breeds

Introduction

Management decisions concerning ewe breed type, lambing season, and when, or if, to wean lambs are specific to each sheep operation and are influenced by forage and feed resources and the desired time of marketing. The choice of ewe breed type and lambing season are generally strategic decisions made to optimize marketing opportunities and the integration of the sheep enterprise into overall farm operations. Choice of when to wean lambs is more often a tactical decision aimed at optimizing lamb performance, but should also involve consideration of effects on marketing options and cost of gain.

Spring-born lambs are often weaned in early or mid-summer to allow lambs access to the best summer forage and to remove lambs from the ewes, which are a primary source of internal parasite infestation for lambs (Lewis et al., 1972). Whether weaned or nonweaned, spring-born lambs can be marketed directly off pasture, usually as feeder lambs, or can be moved to drylot to be finished and marketed in fall. Fall-born lambs tend to be weaned as fall pastures are depleted and fed in drylot to be marketed as prices rise in spring.

The weaning process can slow growth, even in lambs that are as much as 6 mo of age (Brown, 1964; Gibb et al., 1981; Lee et al., 1990). Whether or how quickly preweaning growth rates can be recovered depends on preweaning milk intake (Gibb et al., 1981), level of infective parasite larvae on ingested herbage (Lewis et al., 1972), and quality of lamb forage or feed after weaning (Gibb et al., 1981; Pope et al., 1984).

This study compared postweaning performance of lambs from ½-Suffolk, ¼-Rambouillet, ¼-Finnsheep (¼-Finn) ewes to that of lambs from ½-Rambouillet, ¼-Suffolk, ¼-Hampshire (Western) ewes in

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spring or fall lambing. In addition, effects of weaning age on performance of spring-born lambs grazing perennial cool-season pastures during summer were evaluated.

Materials and Methods

Animal Management

This experiment was conducted at the Southwest Virginia Agricultural Research and Extension Center at Glade Spring. The experimental design and preweaning animal management used in this study were described by Tolman and Notter (1999). Briefly, reproduction and lamb performance were compared across 3 yr for Western and ¼-Finn ewes lambing in spring (March and April) or fall (September and October). Lambs were sired by Suffolk x Hampshire rams. Lambs born in spring were creep fed until the onset of spring grazing in mid-April, at which time creep feeding was discontinued. Lambs born in fall grazed turnips (yr 1 and 2) or alfalfa (yr 3) with their dams and were creep fed throughout the preweaning period.

Spring lambs were weighed at approximately 90 d of age in early June and were divided into weaned and nonweaned groups at that time (Table 1). Nonweaned lambs and their dams were continuously stocked on perennial pastures in all 3 yr. In yr 1 and 2, weaned lambs grazed improved pastures fertilized to encourage at least 25% white clover content until they reached market weight or were moved to drylot on September 16 (yr 1) or October 6 (yr 2). In yr 3, weaned lambs were rotated through .4-ha paddocks of the same improved pastures at approximately weekly intervals. All lambs were dewormed with injectable ivermectin at 4-wk intervals throughout the trial. Lambs became heavily infested with internal parasites in mid-summer of yr 1 and 2, and weaned lambs in yr 2 required an additional anthelmintic treatment in August.

Lambs were weighed in mid-July in all 3 yr, and in early August and mid-September of yr 1 and 2 (Table 1). In yr 3, unusually dry weather conditions caused lambs to be weaned on August 4 and lambs in yr 3 were subsequently weighed and moved to drylot on September 4. For this reason, lamb performance after mid-July in yr 3 was not included in the analysis of weaning effects on lamb growth.

Spring lambs were marketed as they reached a minimum live weight of 48 kg. Lambs not marketed by the end of the grazing period were moved to drylot in early September (Table 1). Drylot feed in yr 1 and 2 consisted of .23 $kg \cdot head^{-1} \cdot d^{-1}$ of grass-clover hay plus ad libitum access to a 13.5% CP ground corn-soybean meal mixture. Drylot feed in yr 3 consisted of a 9:1 mixture of whole corn and pelleted protein supplement fed ad libitum. Any lambs not weighing 48 kg by September 30 in yr 1 and 2 or by November 30 in yr 3 were marketed at those times.

Fall-born lambs (n = 55 in yr 1, 45 in yr 2, and 33 in yr 3) were weaned directly to drylot when their dams finished grazing turnips in yr 1 and 2 (Tolman, 1993) or alfalfa in yr 3. Weaning dates in yr 1, 2, and 3 were December 2, November 21, and November 16, respectively, and mean weaning ages were 74, 68, and 73 d, respectively. Drylot rations were the same as described above for spring-born lambs in each year. Fall-born lambs were again weighed on February 4, February 3, and January 18 in yr 1, 2, and 3, respectively, to determine postweaning daily gain and were then marketed as they reached a weight of 48 kg. Lambs that did not weigh 48 kg by March 31 were marketed on that date.

Traits evaluated in this study were lamb daily gain after weaning or during late lactation, and lamb age and weight at marketing. For spring-born lambs, daily gains were evaluated from about 90 d of age in early June to mid-July (Period A), from mid-July to early August (Period B), and from early August to mid-September (Period C, Table 1). Gain was also evaluated for the entire period from early June to mid-September (Period ABC). Number of days on feed was also analyzed for fall-born lambs.

Statistical Analysis

The summer grazing portion of the trial involved a two-by-two factorial arrangement of treatments within each year. Effects of ewe breed and weaning status (weaned at 90 d versus not weaned) on

Table 1. Calendar for the weaning trial with spring-born lambs

	Year		
Activity	1	2	3
Start of trial	June 5	June 11	May 29
No. of lambs	112	87	78
Mean lamb age, d	92	98	81
End of Period A	July 17	July 8	July 13
End of Period B	August 7	August 5	a
End of Period C	September 16	September 16	a

[a]Lambs were not weighed after July 13 in yr 3.

daily gain in Periods A, B, and C and on age and weight at marketing were evaluated by analysis of variance using the general linear models procedure of SAS (1990). The model included fixed effects of weaning status, ewe breed, lamb sex, and year, the weaning status x ewe breed and weaning status x year interactions, and 90-d weight as a covariate. Effects of weaning status x 90-d-wt interaction on gain were considered in preliminary analyses but were not significant, and so were removed from the model. Growth patterns in Period A were consistent across the 3 yr, so yr 3 data were included in the Period A analysis. Analyses of Periods B, C, and ABC were conducted without yr 3 data, so references to Periods B, C, and ABC include only data for yr 1 and 2. Market weights and ages for yr 3 were analyzed separately.

For fall lambs, effects of ewe breed on postweaning daily gain and age and weight at marketing were evaluated. Data for yr 3 were included in the analysis of fall lamb gain after weaning. Although the drylot feed differed from that fed in the first 2 yr, lambs were allowed ad libitum access in all 3 yr, and management of drylot lambs did not change substantially. Analysis of market age and days on feed, however, did not include yr 3. Lambs weaned from dams on alfalfa in yr 3 averaged 4.3 ± 1.1 kg heavier at weaning than those weaned from dams that grazed turnips in yr 1 and 2, giving yr 3 lambs a weight advantage. Thus market weights and dates for yr 3 were analyzed separately.

Results and Discussion

Summer Daily Gain of Spring Lambs

A random half of the spring lambs were weaned in late May or early June of each year (Table 1). Mean age-adjusted 90-d weights of lambs at this time were 27.0 ± .5, 30.6 ± .5, and 24.8 ± .6 kg in yr 1, 2, and 3, respectively. Weaning status had a significant effect on gain throughout the summer (Table 2). In yr 1 and 2, nonweaned lambs gained an average of 191 ± 5 g/d over the entire summer grazing season whereas weaned lambs gained only 109 ± 5 g/d. This 82 ± 7 g/d advantage of nonweaned lambs over weaned lambs is much larger than that reported by Lee et al. (1990; 14 g/d) or Jordan and Marten (1968; 41 g/d). However, both of these studies involved high-quality forages, with a 50% legume content in the sward grazed by weaned lambs. The grass-clover pasture in the current trial contained approximately 25% white clover. Thus lower forage quality may have accentuated differences in lamb gain.

Nonweaned lambs gained significantly faster than weaned lambs in all periods of all years except Period B of yr 1, when nonweaned lambs grew 14 ± 20 g/d slower (Table 2). In mid-July of yr 1, infestation with internal parasites was pronounced, resulted in some lamb deaths and is reflected in poor gains of both groups in Period B. Nonweaned lambs appeared to recover more quickly as indicated by Period C gains in yr 1 of 223 ± 9 g/d for nonweaned lambs but only 86 ± 9 g/d for weaned lambs. In yr 2, parasite infestation was again a severe problem, resulting in weight loss during Period C in weaned lambs, whereas nonweaned lambs were able to maintain slow growth.

These observations on the impact of internal parasite challenge are supported by research of Lewis et al. (1972) and Watson (1991). Lewis et al. (1972) noted that lambs drenched with thiabendazole at 3-wk intervals, but grazed on pastures with high residual larval populations, grew no differently than undrenched lambs that grazed on pastures with low residual larvae counts. In the current trial, lambs were on pastures that had been grazed by sheep for many years and were expected to have substantial larvae populations. Barger (1988) reported that Merino lambs first developed resistance to *Haemonchus contortus* (the most common intestinal parasite of sheep in Virginia) "as early as" 16 wk of age; the equivalent age would have occurred in early July in the current study. However, Watson (1991) found that at 12 wk of age, antibody responses of Merino lambs to *H contortus* challenge were lower and slower to develop in weaned lambs, suggesting that suckled lambs would be bet

Table 2. Least-squares means and standard errors for summer average daily gain (g/d) of weaned and nonweaned spring lambs.

	Year							
	1		2		3[b]		Combined	
Period[a]	Weaned	Nonweaned	Weaned	Nonweaned	Weaned	Nonweaned	Weaned	Nonweaned
A	182 ± 9	282 ± 9	268 ± 9	291 ± 9	118 ± 9	218 ± 9	189 ± 5	264 ± 5
B	32 ± 14	18 ± 14	191 ± 14	259 ± 14			112 ± 9	139 ± 9
C	86 ± 9	223 ± 9	-77 ± 14	50 ± 14			5 ± 9	137 ± 9
ABC	118 ± 5	205 ± 5	95 ± 5	173 ± 9			109 ± 5	189 ± 5

[a]See Table 1 for definition of periods.
[b]Performance was evaluated only for period A in yr 3.

ter able to withstand parasite infestation.

Year effects were highly significant throughout the trial, and weaning status 100 ± 13 g/d in yr 1, 2, and 3, respectively (Table 2). Weaned and nonweaned lambs all grew poorly in Period B of yr 1, and both groups grew well in the same period of yr 2, with nonweaned lambs gaining 68 ± 20 g/d faster than weaned lambs. The weaning status x year interaction disappeared in Period C and was not significant for gain over the entire summer (Period ABC). These results illustrate that although suckling lambs tend to have superior summer growth on pasture, management or environment can have substantial effects on the relative performance of weaned and nonweaned lambs on pasture.

Breed of dam had no effect on gain during any period of the trial or for either weaning status group. Across the entire summer, lambs from Western ewes gained 155 ± 5 g/d, and lambs from ¼-Finn ewes gained 145 ± 5 g/d. This lack of breed effect concurs with results of Notter et al. (1991) and Fahmy (1989) who found no difference in postweaning gain or slaughter age between spring-born lambs from ¼-Finn or non-Finn ewes. A weaning status x ewe breed effect was observed in Period A ($P < .05$), when weaned lambs of Western dams gained 86 ± 14 g/d less than their nonweaned counterparts, but weaned lambs of ¼-Finn dams gained only 36 ± 14 g/d less than their nonweaned counterparts. However, this interaction was not significant in Periods B and C or over the entire summer.

Wether lambs grew faster than ewe lambs in Period A (18 ± 9 g/d; $P < .05$) but not in Periods B and C. Over the entire summer, wethers gained 14 ± 7 g/d more than ewe lambs ($P < .05$). The 90-d weight varied among years at the start of the trial ($P < .001$), but did not have a significant effect on gain during any period.

Age and Weight at Marketing for Spring Lambs

Both weight and age at marketing were affected ($P < .001$) by weaning status in spring lambs. For yr 1 and 2, weaned lambs were marketed at an average of 43.6 ± .5 kg and 201 ± 2 d of age; nonweaned lambs were marketed at an average of 47.7 ± .5 kg and 186 ± 2 d of age. In these years, an average of 69% of nonweaned lambs, but only 33% of weaned lambs, were marketed at greater than 47 kg by

Table 3. Marketing distribution for spring lambs

	Percentage of lambs marketed in each month for:					
	Weaned lambs in yr:			Unweaned lambs in yr:		
Month/wt[a]	1	2	3	1	2	3
July	0	24	0	4	42	3
August	3	0	0	33	9	10
September at:						
>47 kg	21	18	5	35	15	0
43 to 47 kg	29	18	b	19	22	b
<43 kg	47	40	b	9	12	b
October			53			74
November at:						
>47 kg			38			8
43 to 47 kg			2			3
<43 kg			2			2

[a]In months without specified weight categories, only lambs that weighed more than 47 kg were marketed..
[b]No lambs were marketed at <47 kg in September of yr 3.

Table 4. Least-squares means and standard errors for postweaning daily gain (g/d) of fall lambs.

	Ewe breed	
Year	Western	¼-Finn
1	314 ± 12	259 ± 10
2	241 ± 15	254 ± 10
3	286 ± 16	273 ± 10
Combined	280 ± 8	262 ± 6

September 30 (Table 3). Market age was also affected by year; lambs in yr 2 were marketed 17 ± 3 d earlier than lambs in yr 1 (P < .001), and the pattern of marketing differed somewhat between yr 1 and 2. In yr 1 and 2, 2 and 33%, respectively, of the lambs were marketed in July, but 48 and 54%, respectively, were marketed at greater than 47 kg by September 30. These different marketing patterns seem to be related to the timing of parasite stress, in that parasite infestation appeared to peak in July of yr 1 but not until August of yr 2. This result emphasizes the importance of controlling parasite load in lambs grazing summer pastures. There were no ewe breed or interaction effects on market age or weight; however, the impact of the early parasite infestation in yr 1 appeared to delay marketing more in the weaned lambs (24 versus 72% marketed at >47 kg by September 30).

In yr 3, only 6% of lambs reached market weight before going to drylot on September 4; 74% were marketed by October 31. Average market ages and weights in yr 3 were 49.5 ± .3 kg and 217 ± 3 d for nonweaned lambs, and 50.2 ± .4 kg and 240 ± 4 d for weaned lambs. Twenty-nine percent more of the nonweaned lambs were marketed at >47 kg by October 30 (Table 3).

Postweaning Daily Gain of Fall Lambs

Daily gain after weaning averaged 271 g/d for fall-born lambs over the 3 yr, which was only 29 g/d less than average preweaning daily gain. Ewe breed effects approached significance (P < .10; Table 4); lambs from Western and ¼-Finn ewes gained 280 ± 8 and 262 ± 6 g/d, respectively. Postweaning daily gain was affected by year (P < .01); lambs in yr 2 grew 39 ± 12 and 32 ± 13 g/d less than lambs in yr 1 and 3, respectively, suggesting management or environmental effects on daily gain.

A ewe breed x year interaction was also evident (P < .01; Table 4). Daily gains of lambs from ¼-Finn ewes did not vary significantly over the 3 yr. However, lambs from Western ewes in yr 2 gained only 241 ± 15 g/d, which was significantly less than lambs from Western ewes in yr 1 and 3 (314 ± 12 and 286 ± 16 g/d, respectively). Thus lambs from Western ewes gained significantly more than lambs from ¼-Finn ewes in yr 1 (P = .001) but not in yr 2 or 3. Lambs from Western ewes in yr 2 did not differ in preweaning gain from those in yr 1 or 3. The reduced postweaning gain in yr 2 appeared to be a function of age at weaning: because of later average birth dates, lambs from Western ewes averaged 60 d at weaning in yr 2, compared to 72 and 68 d in yr 1 and 3, respectively. Lambs from ¼-Finn ewes averaged 76, 72, and 75 d of age at weaning in yr 1, 2, and 3, respectively.

Age and Weight at Marketing for Fall Lambs

For fall lambs, market age, market weight, and number of days on feed were not affected by ewe breed. Lambs from ¼-Finn ewes were marketed at an average weight of 49.5 ± .5 kg at 164 ± 3 d of age after 92 ± 3 d on feed. Lambs from Western ewes were marketed at an average weight of 50.4 ± .7 kg at 164 ± 3 d of age after 100 ± 4 d on feed. The difference in market age between spring- and fall-born lambs (194 vs 164 d, respectively) is attributable to use of forage-based versus concentrate-based diets. The difference in market age is not as pronounced as that reported by Notter et al. (1991), primarily because growth of spring lambs in that study was hampered by drought-limited forage and lambs were consequently not marketed until an average of 234 d of age. These results confirm the influence of weather conditions on summer lamb performance.

Days on feed were affected by year (P < .05) in fall lambs. Lambs in yr 1 spent 16 ± 5 d less in drylot than lambs in yr 2. This result can be explained in large part by their respective weaning dates; lambs in yr 1 were weaned 11 d later than lambs in yr 2. Ewe breed x year interactions were only significant for days on feed (P < .05). This result mirrors the interaction effect on daily gain after weaning, wherein daily gain of lambs from Western ewes in yr 2 was 82 ± 18 g/d less than in yr 1, and their time on feed was consequently extended. Marketing patterns (Table 5) were similar for yr 1 and 2, with an average of 56% of the lambs marketed at >47 kg by the end of February and an average of 91% marketed at >47 kg by the end of March. Changes in the postweaning diet in yr 3 resulted in earlier marketing; all lambs were marketed at >47 kg by February 28.

Table 5. Marketing distribution for fall lambs

	Percentage of lambs marketed in each month in yr:		
Month/weight[a]	1	2	3
December	8	0	15
January	13	15	64
February	40	35	21
March at:			
>47 kg	26	45	
43 to 47 kg	6	4	
<43 kg	7	1	

[a]In months without specified weight categories, only lambs that weighed more than 47 kg were marketed.

Conclusions

Spring-born lambs grew much faster after 90 d of age if they remained with their dams during the summer grazing period. Lambs weaned at 90 d to graze improved perennial pastures were less able to withstand, or recover from, internal parasite challenge. The effect of weaning was not influenced by breed type.

Fall-born lambs grew faster after weaning than spring-born lambs. This result was attributed to the high-concentrate drylot diet, cooler ambient temperatures, and reduced ingestion of parasite larvae. Also, greater preweaning rates of gain and consequently heavier weaning weights of fall lambs resulted in younger ages at marketing. Lambs from ¼-Finn ewes grew slightly slower in drylot after weaning than lambs from Western ewes.

Lamb market ages and weights can be altered by choice of feedstuffs. Fall-born lambs in this study could have been fed on a higher roughage diet to delay marketing; conversely, spring-born lambs could have been supplemented with grain to reach market weights earlier. Between-season comparisons are therefore limited to the nutritional conditions and management choices made for this study.

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Copper Toxicosis in Sheep: A Review

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Summary

Sheep are more susceptible to copper toxicosis than most other agricultural animals. Their susceptibility results from their inability to detoxify and excrete high loads of this mineral. In other species, an increase in copper intake stimulates the synthesis of a low molecular weight protein, metallothionein, which binds ionic copper and reduces its toxic effect. Copper intake in sheep has a less stimulating effect on metallothionein synthesis, allowing a greater amount of ionic copper to enter the liver. Because of the lower concentrations of liver lysosomal metallothionein, the rate of bile copper excretion is lower in sheep compared to other animals. Copper toxicosis in sheep can be either acute or chronic. Acute toxicosis occurs when excessively high doses of copper are given, causing an immediate lipid peroxidation of erythrocytes and of the cells lining the intestine, liver, and kidneys. Death usually occurs within 24 to 48 hours. Chronic toxicosis is more common and occurs from accumulated doses of copper over weeks or months. The copper is deposited in the liver until liver tissue is damaged to the point that copper is rapidly released causing peroxidation of erythrocyte and other tissue membranes. In both cases, death is imminent due to hemolytic crisis (destruction of erythrocytes in the blood). Chronic toxicosis is treated more easily than acute toxicosis. Treatment is not always successful but is performed by reducing the intake of copper, increasing the rate of copper excretion, and/or complexing copper to prevent its reactivity with tissues. Molybdenum therapy is the most widely used method of complexing copper in the body and reducing copper absorption. Dietary molybdenum, especially in the presence of sulfate, reduces copper availability by forming an insoluble complex in the intestines. Recommended doses are 100 mg of ammonium molybdate and 1 g of sodium sulfate per day (oral) for 6 d or 1.7 to 3.4 mg/kg live body weight of ammonium molybdate (subcutaneous) in three alternate day injections. Penicillamine (50 mg/kg body weight) can be administered orally on a daily basis for up to 6 days. Limited data exist in the literature on the production efficiency of animals that apparently have recovered from copper toxicosis.

Key words: Sheep, copper toxicosis, treatment.

Introduction

Sheep are more susceptible to copper toxicosis than any other animal used for meat, milk or fiber production. In the absence of an antagonist, the maximum tolerable levels of copper for the following species during growth are sheep, 25 ppm; cattle, 100 ppm; swine, 250 ppm; horses, 800 ppm; and poultry, 300 ppm (NRC, 1980). There are limited data available on copper toxicosis in goats, but it is thought that they rank between sheep and cattle in sensitivity to high copper levels (Kessler, 1991). Generally, growing animals are more sensitive to copper toxicosis than mature animals (NRC, 1980) and can exhibit sublethal reductions in growth (Ely et al., 1989).

In most sheep production environments, copper toxicosis is more likely to occur in growing lambs consuming diets that include high-copper mineral supplements by mistake. A case in point occurred at the Texas A&M University Agricultural Research Station at Sonora during the fall and winter of 1997-98 (de la Concha-Bermejillo et al., 1998). Ram lambs that were being evaluated for growth rate and wool production in the Texas Agricultural Experiment Station Ram Performance Test were observed to have signs of copper toxicosis. Several of the rams died, and it was determined, on postmortem examination, that the lesions were consistent

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with copper poisoning. Feed samples that had been collected as the feed arrived were analyzed after the signs became apparent. The analyses indicated that copper levels in the feed, between September 15 (beginning of test) and January 28, averaged 68 ppm (range, 17-133 ppm). Of the 211 ram lambs that began the test, 17 died from what was considered copper poisoning over a two-month period beginning December 8, most showing classical signs of copper toxicosis including acute hemolysis.

This manuscript will discuss copper metabolism, acute and chronic toxicosis, and the treatment and prevention of this malady.

Copper Function in Normal Mammalian Metabolism

The dietary requirement for copper in sheep is 5 to 8 ppm when no dietary antagonists are present. Grazing sheep can become deficient in this mineral due to an inadequate intake or the presence of an antagonist. Greene et al. (1999) reported the range of copper in Texas Bermudagrass and native forages to be <1 to 16 ppm and <1 to 12 ppm, respectively. Nineteen and 46% of the Bermudagrass and native forages, respectively, were less than 5 ppm. Consequently, supplementation with copper may be beneficial, especially when the animals have limited dietary choices. In other situations, supplementation with copper may cause copper poisoning. In sheep, the margin of safety for supplementing copper is very narrow. (NRC, 1980). Van Saun (1988) stated that grazing sheep are generally less likely to become copper intoxicated than those fed mixed diets because of low copper availability of forages. Forages may contain elevated levels of antagonists that reduce copper availability. Elevated intakes of molybdenum, sulfate, zinc, calcium, and soil will limit the amount of copper absorbed from the digestive tract. In the absence of these antagonists, sheep provided with high copper mineral supplements or graze forages fertilized with copper, swine waste, or poultry litter may succumb to copper toxicosis.

Copper functions in normal metabolism as a component of many enzyme systems. These enzymes are physiologically active in cellular respiration, red blood cell activity, connective tissue development, myelination of the spinal cord, keratinization, melanin pigment formation, and immune responsiveness (McDowell, 1992). Reduced cellular respiration and impaired energy metabolism occur because of low cytochrome oxidase activity during a copper deficiency. Both iron and copper are necessary for hemoglobin synthesis although copper is not contained in hemoglobin. A deficiency of either element results in anemia. The enzyme lysyl oxidase is a copper-containing enzyme involved in the maturation of collagen that is especially important in fetal development. Newborn lambs from copper-deficient dams may have difficulty standing shortly after birth. Additionally, copper deficient animals will be susceptible to aortic aneurisms due to a lack of elasticity in the vascular system. The role of copper in the synthesis of keratin protein is apparent in the proper crimp in wool. This wavy appearance is created by the presence of disulfide linkages that require the action of copper. Other maladies that may appear when copper is deficient include enzootic ataxia (sway back), caused by incomplete nerve formation and acromotrichia (lack of pigment) resulting from a low production of melanin. Suttle and Jones (1989) reported that lambs deficient in copper were more susceptible to microbial infections. They also reported that lambs low in copper had less resistance to parasitic infection compared to those consuming and absorbing adequate copper.

Under normal circumstances, Cu is absorbed readily from both the small and large intestines (Grace, 1975). Grace and Clark (1991) reported the amounts absorbed are influenced by the physiological status of the animal, level of intake of copper, and interactions with other mineral elements and their metabolites. They reported over 90% of the copper ingested by suckling lambs is absorbed but the absorption efficiency in weaned lambs decreased to 9%. Wooliams et al. (1985) reported Welsh Mountain sheep are 50% more efficient in absorbing copper and have higher plasma and liver concentrations than Scottish Blackface sheep. Copper absorption is regulated by metallothioneins, which are low molecular weight proteins that selectively bind metal ions (Dunn et al., 1987). Metallothioneins are synthesized in the presence of heavy metals and are important in preventing and reducing heavy metal poisoning. In the case of copper, metallothioneins regulate its metabolism (Dunn et al., 1987). Saylor et al. (1980) suggested that sheep have a limited capacity to synthesize metallothionein in response to increased copper intake. Furthermore, Mehra and Bremner (1984) reported that the function of metallothionein, in lysosomal storage and detoxification of copper in the liver during copper loading, is impaired in sheep. Metallothionein concentration in the liver is a function of dietary zinc, which can be displaced from metallothionein in both the intestine and liver by copper. The bile is the major route of excreting excess absorbed copper from the body (Gooneratne et al., 1989). Although little is known about the mechanism of bile copper excretion in sheep, these workers suggested the combined effect of low liver lysosomal metallothionein and the lack of metallothionein synthesis during high intakes of copper may be the primary reason why sheep are more sensitive to copper toxicosis than other animals.

Acute and Chronic Copper Toxicosis in Sheep

Both acute and chronic toxicosis of copper are problematic for the sheep industry. The final result of either, if left untreated, is death, but the observed symptoms are different. Signs of acute toxicosis of copper occur within 24 to 48 h of a consumed dose and include salivation, abdominal pain, convulsions, paralysis, collapse, and death (NRC, 1980). Sheep dying from acute copper toxicosis suffer from severe gastroenteritis (and in some cases a ruptured abomasum), necrotic hepatitis, spleen and kidney damage (damage and loss of function of tubular cells), and intravascular coagulation (NRC, 1980). Acute toxicosis usually occurs from accidental overdosing or accidental consumption of copper-containing anthelmintics.

Copper that is bound to proteins or other compounds is not toxic. Toxicosis occurs from a high load of ionic copper. The damage to the intestine, liver, spleen, and kidney appears to result from lipid peroxidation of cellular membranes and the lack of antioxidants to prevent this oxidation (Bostwick, 1982). Van Saun (1988) indicated that a high level of ionic copper overwhelms the enterocyte metallothionein, allowing copper to act directly on intestinal cell membranes. This action induces a lipid peroxidation and protein coagulation. A massive cellular degeneration occurs, allowing excessive amounts of copper to saturate the plasma transport system (albumin). Large amounts of copper are then transported to the liver and other organs where they cause severe membrane damage. Damage to the red blood cell (RBC) membranes causes their rapid destruction, creating the hemolytic crisis, which leads to death. The rapid influx of copper overwhelms the body's ability to repair these tissues in a normal fashion. Copper ions oxidize membrane lipids in RBC's, making the membranes more fragile, reducing hemoglobin, and increasing methemoglobin (a copper-containing compound similar to hemoglobin). Both hemoglobin and methemoglobin appear in the urine, causing renal tubule necrosis and failure. Mortality occurs in over 75% of the acute toxicosis cases (Van Saun, 1988).

A chronic toxicosis of copper causes similar damage to the RBC's and results in a hemolytic crisis (Kidder, 1949), but it develops under different circumstances (Van Saun, 1988). Damage to the intestinal tract is not as severe or is often, nonexistent. The dietary copper is not in sufficient excess to cause drastic tissue damage during absorption but is accumulated in the liver and other tissues more rapidly in sheep than in other species. This accumulation is the result of a lesser ability of sheep to excrete copper, through the bile and urine, compared with other species (Van Saun, 1988). During the development of chronic toxicosis, diagnostic signs are absent until body levels reach a critical point. When liver levels of copper reach high concentrations and liver cell damage occurs, large amounts of ionic copper enter the blood stream, causing widespread hemolysis. Sansinanea et al. (1993) reported that ewes fed a diet containing 52 ppm copper maintained normal serum copper for 9 wk then showed a dramatic increase of serum copper beginning week 10. By week 11, serum copper had increased threefold. An increase in lipid peroxidation of the RBC's occurred simultaneously with a decrease in superoxide dismutase (an antioxidant enzyme) activity. Ely et al. (1989) found serum aspartate aminotransferase (AST) a good indicator of copper toxicosis prior to reduction in performance. Other enzymes, including glutamyltransferase and creatine kinase, also are sensitive to copper levels (Auza et al., 1999).

Acute toxicosis of copper occurs in a single phase whereas chronic toxicosis occurs in two phases. The NRC (1980) and King and Bremner (1979) described the two phases of chronic toxicosis as 1) accumulation of copper in tissue (most notably in liver and kidney) and 2) acute illness to include hemolytic crisis. The accumulation phase may take place over several weeks or months. The length of time will be affected by level of copper consumed, age of animal, breed of animal, source of copper fed and level of copper antagonist in the diet. Liver copper levels will increase from a normal range (6 to 300 ppm) to a high range (1000 to 3000 ppm) while serum copper stays normal followed by a sudden increase to high levels (NRC, 1980; King and Bremner, 1979). The shift from normal to high serum copper is the onset of the second phase of toxicosis when physical symptoms are displayed. Animals will appear jaundiced because of a severe liver dysfunction and will have dark-brown urine caused by the excretion of breakdown products of damaged RBC's. During hemolytic crisis, sheep become icteric and have swollen partially cirrhotic livers and very dark hemoglobin-stained kidneys.

King and Bremner (1979) showed histological and histochemical changes in liver during the prehemolytic phase of toxicosis. These changes were related to liver copper concentrations and were most noted initially in the periportal regions but migrated to the central veins as copper concentration increased. They noted the first change was an increase in eosinophilia of parenchymal cells surrounding the portal tracts. These cells often contained fine particles containing copper that increased in number and size as liver copper concentrations increased. When liver copper concentrations exceeded 200 mg/kg, copper loaded particles were found further down the lobular gradient. Towards the later stages of the prehemolytic phase, the incidence of single cell necrosis increased along with an enlargement of nuclei and mitochondria. No evidence exists in the literature to identify the effects of this liver damage on long-term production efficiency after the chronic toxicosis was halted before the initiation of phase 2. Gopinath et al. (1974) reported gross abnormalities of the kidneys not seen before hemolysis occurred. They reported the only discernible change was the presence of eosinophilic intracytoplasmic granules in the epithelium of the proximal convoluted tubules. After the hemolytic crisis, kidneys were swollen and blue-black in color. Histologically, there were degeneration and necrosis of the tubular epithelium. Once the second phase of chronic toxicosis is initiated, the likelihood of recovery is much reduced.

Treatment and Prevention of Copper Toxicosis in Sheep

Affected animals show both transient and permanent damage from copper poisoning (Andrés de la Concha, personal communication). Whereas the literature is rich in the causes, diagnosis, treatments, and prevention of copper poisoning in sheep, it is remarkably silent on the permanency of damage and expectations for full recovery. Whether the liver damage caused by copper poisoning is reversible is not clearly indicated although many references cite evidence that copper levels in the liver can be reduced and symptoms will subside (Davis and Mertz, 1987). However, the disappearance of external symptoms does not necessarily mean the animal has returned to normal and productivity has not been reduced. High liver copper levels can linger long after elevated copper in the diet has stopped (Olsen et al., 1984), and an acute hemolytic crisis can result from the sudden release of stored copper from the liver (Barden and Robertson, 1962; Gooneratne et al., 1981).

Treatment of copper-intoxicated sheep should include the reduction of copper in the diet and the reduction of copper contained in the body, especially that stored in the liver (Auza et al., 1999). Molybdenum therapy is useful in treatment of copper toxicosis because it interferes with the absorption of copper (Davis and Mertz, 1987; Van Saun, 1988) and complexes tissue copper, hastening its excretion from the body (Hidiroglou et al., 1984; Ross, 1970). The sulfate ion also aids in the increased excretion of copper from the body, possibly in concert with molybdenum as thiomolybdate (Gooneratne et al., 1981; Gooneratne and Christensen, 1997). The route of excretion of copper complexed with thiomolybdate is primarily through the bile/feces (Hidiroglou et al., 1984; Gooneratne and Christensen, 1997). Molybdate is effective when administered orally with sulfate (100 mg ammonium molybdate and 1 g sodium sulfate per d for 6 d; Van Saun, 1988) or when injected intravenously or subcutaneously as ammonium tetrathiomolybdate (1.7 or 3.4 mg/kg live body weight, respectively) in three alternate day injections (Humphries et al., 1988). Penicillamine is an effective decoppering agent that increases excretion of copper via the urine (Gooneratne and Christensen, 1997). It can be administered orally in doses of 50 mg/kg live body weight daily (Van Saun, 1988; Soli et al., 1978) for up to 6 days. Other chelating agents including disodium calcium ethylenediamine tetraacetate, 2-3 dimercapto-1-propanol, and dimethyl dithiocarbamate are relatively ineffective (Van Saun, 1988).

Copper toxicosis seldom occurs under most normal circumstances. Danger levels and safe conditions can be defined, but there is great variability among animals in susceptibility to copper toxicosis (NRC, 1980). Several elements including iron, calcium, and zinc influence copper absorption and metabolism. However, the most important relationship is among copper, molybdenum, and sulfate (Davis and Mertz, 1987). Copper at a moderate level (10 ppm) in the diet can be deficient if molybdenum is very high (>5 ppm) or toxic if molybdenum is very low (<.1 ppm). Sulfate generally enhances the antagonistic effect of molybdenum on copper. It should be understood that conditions leading to copper deficiency or copper toxicosis are the exceptions from the normal. However, the devastation caused when copper poisoning does occur can be substantial, and the sheep producer should remain alert to danger signs. Toxicosis will occur if the diet is high in copper content (usually >20 ppm) with moderately low Mo (<1 ppm), the diet is normal to moderate in copper content (5 to 20 ppm) and very low in Mo (<.1 ppm) (Davis and Mertz, 1987; NRC, 1985), or mineral supplements are provided that contain excessively high amounts of copper (NRC, 1985). This often occurs when supplements formulated for other species (cattle, horses, hogs, etc) are fed to sheep (J.C. Reagor, personal communication). Another common circumstance of copper poisoning is with accidental or uninformed administration of a high-copper substance such as copper sulfate (for control of algae in water troughs) and anthelmintics. On the other hand, a deficiency can occur if copper is low in the diet (<5 ppm), copper is low to marginal (5 to 8 ppm) and Mo is normal to moderate (>1 ppm), or copper is normal (5 to 15 ppm) and Mo is high (>5 ppm) with high sulfate (>.5 %) (NRC, 1985). If copper toxicosis is suspected or diagnosed, it is recommended that the diet be adjusted so copper content is less than 15 ppm in finewool sheep (<10 ppm in medium wool sheep) and that Mo content is from 1 to 3 ppm.

In the Ram Performance Test case described in the introduction, a follow up study was conducted to determine if the intoxicated rams could be saved by molybdenum therapy. Beginning on February 3, a test was conducted with 28 rams belonging to the Texas Agricultural Experiment Station that were a part of the performance test from the outset. Four were euthanized in order to obtain initial information of the current state of copper toxicosis. The remaining 24 rams were divided randomly into two groups of twelve which were further divided into replicate groups of four rams per group. Twelve of the rams (three pens of four rams each) were fed the original feed that was reformulated and analyzed to contain 16.5 ppm copper, 2.9 ppm molybdenum, and .19% sulfur. The other 12 rams were fed the same formulation, except it was enriched with sodium molybdate to contain 50 ppm molybdenum. The rams were fed the diets for 3 wk, then four rams from each group were euthanized for postmortem examination. Six of the 12 control rams died during or just following the 3-wk feeding period with signs consistent with copper poisoning. None of the rams receiving the elevated molybdenum died. Copper levels were higher (P<.5) in serum and lower (NS) in livers of rams consuming the molybdenum diet. This is consistent with the expected effect that the molybdenum moved the copper from the liver into the blood in a non-reactive form that would then be excreted through the bile (Gooneratne et al., 1981). Approximately 6 months after the 3-wk test, all surviving rams (two control and eight molybdenum-fed rams) were semen tested. Two rams tested weak (both from the molybdenum-fed group) and the rest strong. Two control and two molybdenum-fed rams were each placed with 20 ewes for breeding. Recorded breeding marks indicated all rams performed normally. In March of 1999, the numbers of ewes that were dry (had not lambed or were not pregnant) were 2 and 1 for the control ram groups and 2 and 4 for the groups bred by molybdenum-fed rams. This suggested that the copper-intoxicated rams were reproductively sound, at least when bred to a limited number of ewes.

Conclusion

Copper toxicosis in sheep is not likely under most grazing conditions. However, under exceptional grazing conditions, in confinement when complete diets are fed, when formulated mineral supplements are offered, or when animals are being treated for health problems with high-copper substances, copper toxicosis can occur. Suspect copper poisoning when pastures are fertilized with poultry or swine manure that is high in copper. Also be suspicious of areas that are reputed to be extremely low in molybdenum. Copper should not be included in the mineral concentrate used to formulate complete rations for sheep. It is extremely important that sheep not be offered a mineral supplement that was enriched in copper for other livestock species. If toxicosis occurs, the animals should be detoxified using a high molybdenum/sulfate diet or other means as described above. Whereas animals appear to recover from copper toxicosis, evidence of subsequent normal production is inadequate at present.

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Selection for Litter Size or Weaning Weight in Range Sheep

I. Selection Practiced and Direct Response [1]

H. Sakul [2], G.E. Bradford [3], and M. R. Dally

Abstract

Selection was practiced for more than 30 years for increased litter size or 120-day weight in closed lines of grade Targhee sheep, in a range environment characterized by relatively low forage quantity and/or quality during several months of each year. Initial screening of a flock for high litter size ewes produced an increase of .09 lambs/litter (6%), but an additional 30 years of selection produced a further increase of only .08, for an estimated realized heritability for the latter period of .011. In spite of this low value, the total response represents a potentially significant economic advantage for the selected line over the unselected control. Realized heritability for 120d weight was .06 and .08 in two selected lines, also lower than many reported estimates of heritability for the trait, but the accumulated gain represents approximately a 17% increase above the control. One of the two weight selected lines also showed a significant increase in litter size. Correlated responses and estimated impacts of the selection on total lamb production are reported in a companion paper.

Key Words: Sheep, selection, litter size, weaning weight, realized heritability

Introduction

Total lamb production per ewe is mainly influenced by litter size and lamb growth rate. While growth rate is moderately heritable and has been strongly emphasized in industry selection programs, litter size has consistently low heritabilities. Until the reports of successful selection for litter size by Turner et al. (1962) and Wallace (1964), breeders generally predicted that such selection would be ineffective. However, response to selection depends on phenotypic variability and heritability, and the coefficients of variation for litter size and traits strongly influenced by it are much higher than for measures of growth rate. Thus, selection for litter size may have much more impact than indicated by its heritability estimates.

Another important issue is whether genetic differences are expressed equally in different environments. For example, do heritability estimates obtained from purebreds maintained under favorable feeding and management conditions predict accurately the response to selection under range conditions? Producers are interested in whether genetic improvement made in purebreds is expressed to the same degree under range conditions, and whether it represents improvement in the components most essential to range flock productivity.

In 1959, an experiment was set up to compare the effects of selection for lamb weaning weight in range sheep and under conditions similar to those in purebred flocks; rams from the latter were then used in a separate line in the range environment. Results of that phase were reported by Lasslo et al. (1985a,b). Estimated and realized heritabilities were both higher under the more favorable conditions, but there was little advantage in the selected trait when males from that line were used in the range flock, and fertility and lamb viability were lower in the

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line sired by "imported" males.

Subsequent to initiation of the weaning weight selection, a line selected for multiple births was developed in the range environment from the same base stock. We report here the results of that selection, along with the results of an additional 14 years of selection for 120-day weight, all under range conditions. In a companion paper (Bradford et al., 1999), we compare the effects of selection for weaning weight and for multiple births on fitness traits and total 120-day weight of lamb per ewe. Summaries of portions of these data were reported earlier (Sakul et al.,1994; Bradford et al.,1994).

Materials and Methods

Environment
The experiment was conducted at the University of California Hopland Research and Extension Center in Mendocino County in the North Coast Range of California. The 2150 hectare station represents an annual grassland/oak woodland/chaparral ecosystem with cool wet winters and hot dry summers (Lasslo et al., 1985a). Carrying capacity of different pastures varies widely, but is generally low, averaging less than one sheep per hectare on a year-round basis. Forage is deficient in energy during late autumn and early winter and in protein during much of the dry feed season, which averages 6 months or more annually, and is often deficient in both during late summer and early autumn. As a result, sheep performance levels for reproduction and growth are relatively low. However, this general ecosystem is representative of several million hectares of land for which one of the few agricultural uses is livestock grazing.

Animals
The foundation stock was a crossbred "whiteface" population derived from Rambouillet, Merino, Corriedale and Targhee breeds. The sheep averaged 70 to 75% finewool ancestry and closely resembled Targhees in performance and appearance (Lasslo et al., 1985a).

In 1959, ewes from this base population were allocated at random within age, sire and flock of origin to weight selected and control lines in two locations, Davis (lines DW and DC) and Hopland (lines HW and HC). An additional line at Hopland (DH) was included to evaluate the performance under range conditions of progeny of rams (DW) selected under more favorable conditions. To help ensure a common starting point for all lines, the same sets of rams (12 in total) were mated to ewes in all lines in both locations in 1959 and 1960. Selection for 120-day lamb weight (120W) was initiated in the two locations in 1961. Further details of the experimental design and results of the weight selection in two locations were reported by Lasslo et al. (1985a,b).

In 1963, foundation stock ewes in all lines and additional groups of ewes of similar breeding in the two flocks were screened

Table 1. Description of lines

Line	Selection criterion	Approx. N/yr Rams	Approx. N/yr Ewes	Years in Hopland Flock	Comments
HW	120-day Wt.[1]	5	80	1961-94[3]	Closed line
HC1	Unselected Control	5	40	1961-94[3]	Closed line
HC2	Unselected Control	5	40	1961-77	Closed line
DC	Unselected Control	5	40	1977-83	Closed line
DH	120 day Wt.[1]	5	60-80	1961-94[3]	Mated to rams selected at Davis (DW) 1961-77. DW and DH merged 1977, continued as closed line 1977-94.
HT	Litter size[2]	5-7	90-130	1964-94[3]	Ewes screened from other lines in 1963, with a few added 1964-75. Ewes selected at Davis 1964-72, merged with HT 1972. HT closed after 1975.

1. Ram lambs selected for 120-day wt. adjusted for type of birth and rearing and age of dam. Little selection of ewes.
2. Ram lambs selected on dam's lifetime litter size born. Limited selection of ewes on own litter size.
3. 1995 results included for litter size only.

on the basis of average number of lambs born per parturition (litter size) and the best approximately 20% of older ewes on this measure were assigned to lines in each location selected for litter size. The litter size lines were not closed for several years, i.e. a few of the highest litter size 5-year-old and older ewes from the weight-selected and control lines were assigned to the multiple birth lines. Both the initial and subsequent screening of lines HC, HW and DH involved only ewes leaving those lines based on age, so no selection against litter size in those lines resulted from the creation of the multiple birth lines. This practice did result in a slightly higher mean age in the litter size lines. In 1972, the Davis multiple birth line (DT) ewes were transferred to Hopland and merged with the Hopland multiple birth line (HT), which was continued as a single line thereafter. Additional details on this line are provided by Neira (1989). As described by Lasslo et al. (1985a), the Davis weight-selected and control lines were also transferred to Hopland in 1977. The DW line, genetically essentially the same as the DH line since only DW rams had been used in DH, was merged with the DH line. Line DC was maintained as a separate line at Hopland through 1983.

In this paper, we report only data from sheep in the Hopland flock. Information on the different lines is summarized in Table 1. Data are reported on 120-day weight (120W) and litter size of all lines for all years at Hopland. The data on the weight-selected and control lines through 1980 were also reported by Lasslo et al. (1985a,b); they are included here to provide estimated breeding values based on the complete data set and to show time trends over the course of the entire experiment.

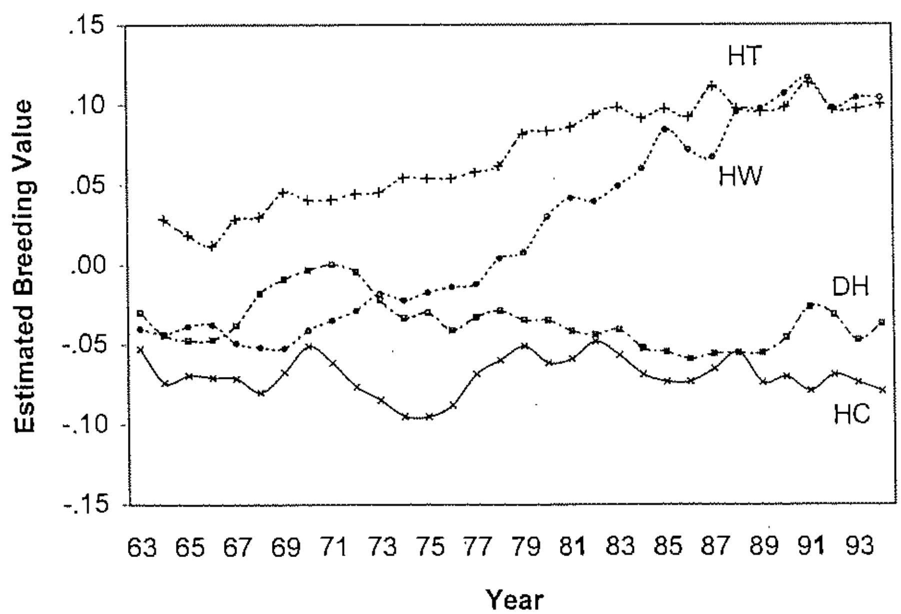
Selection and Mating Plan

Rams in the weight-selected lines were chosen on the basis of 120W adjusted for age of dam and type of birth and rearing (TBR) (Osman and Bradford, 1965; Lasslo et al. 1985a) with the restriction that at least three and usually four or five sires were represented among the five ram lambs selected each year.

Rams in the litter size line were selected on dam's lifetime mean litter size with a similar restriction on number of sires represented. Where ram lambs were available from dams with similar estimated breeding value for litter size, rams from younger dams were favored. Twin ram lambs from high-performance dams were usually both kept at weaning, but normally only one was used for mating. Rams in the control lines were selected at random within sire, i.e. with each sire replaced by a son whenever possible, and with the additional restriction that an attempt was made to select singles and twins in proportion to their incidence in that lamb crop.

In lines HW and HT, nearly all rams used for mating were used as lambs at 6 to 8 months of age. Through 1977, DH rams were yearling rams which had been used for mating as ram lambs in the Davis flock, and thus generation interval would be the same as in lines HW and HT, except for the initial one-year lag. After 1977, ram lambs were used in DH, as in HW and HT. Ram lambs selected at weaning at four months of age or less were full-fed a pelleted diet from weaning until breeding, and there was no problem with rams from the weight lines being too small for mating. In the HT line, a decision was made to pick only rams judged large enough to breed, usually 45 kg or heavier at start of mating, in order to keep gen-

Figure 1. Estimated Breeding Values (EBV) for litter size for lines of sheep selected for multiple births (HT) or 120D weight (HW, DH) and an unselected control (HC).



eration interval low. This resulted in some selection for weight in the HT line. Selection differentials for litter size were reduced only slightly by this practice, as few rams were rejected on the basis of small size.

Ram lambs in the control lines were used the first year, but some of the smaller ones failed to breed. Thereafter, to avoid the selection for weight introduced by this effect, C rams were used first at one year and in most cases used for two years, with half replaced each year to provide sire links between years and to reduce generation turnover. Analyses of lambing dates and fertility showed little effect of ram age on either variable.

There was very little selection of ewes in any line. The flock was subject to heavy coyote predation throughout the project, with intermittent losses to domestic dogs, mountain lions and bears. This, coupled with the relatively low reproductive rate imposed by the environment and the assignment of some ewes at random to linecross matings in several years, left little room for selection of females. All sound females available were added to the breeding flock at approximately 18 months of age and remained in the flock until four or five years of age or older, depending on numbers needed. The two exceptions to this were that ewes dry two consecutive years were culled from all lines, and there was some culling of less prolific ewes from the HT line beginning at four years of age.

Ewes were assigned randomly to rams with the exception that son to dam matings were avoided. Sib matings were effectively precluded in all selected lines by the use of ram lambs while ewes did not enter the breeding flock until a year later. Sib matings could have occurred occasionally in the control lines.

In several years, linecross matings were made. Since there was no evidence that this affected litter size, data on litter size for all ewes within a line were included whether the lambs produced were from within line or linecross matings. However, no linecross data were included in the analysis of 120W. Numbers of lambs with 120W are therefore less than expected based on numbers of ewes lambed in several cases.

As indicated in Table 1, there were three unselected control groups included in the experiment. HC1 was present continuously 1961-1994. HC2 was present 1961-1977; numbers had declined below the target 40 ewes due to chance sex ratio variation and predation, and with the transfer of the DC line to Hopland in 1977, HC2 was discontinued. Preliminary analyses of the data from these three closed lines showed no significant differences among them in litter size or 120W, and the three were therefore treated as one group (HC) for the results reported here.

Management

Ewes in all lines were managed as one flock under range conditions throughout the year except at mating and for a variable period at lambing. Approximately two weeks prior to mating, the ewes were gathered and fed a ration of approximately 2 kg/head/day of alfalfa hay or pellets in confinement until mating, which normally began between August 7and 10. Teaser rams were run with the ewes during the flushing period. The ewes were then divided into single-sire mating pens, in confinement, for approximately 35 days, then returned to the range with either Suffolk rams immediately or whiteface rams one week later. Data from lambings from these clean-up matings were excluded from analyses of 120W.

For the 1969 and 1970 mating seasons, approximately half the ewes in each line, allocated at random, were mated on the range without supplement with the remainder managed as described above. As expected, this treatment had a significant effect on litter size (and also resulted in a line by treatment interaction, Bradford, 1972). Litter size data for all matings on the range were excluded from analyses for this trait. However, ewes from both treatments were managed alike after the one-month mating season and weights on their lambs are included in the analyses of 120-day individual lamb weights.

Mating began early August for the period 1959-1990. In 1991 and 1992, ewes in all groups were mated beginning June 20 to determine if there were any differences among the lines in ability to breed early in the season. In 1993 and 1994, the start of breeding was delayed until September 15 to determine if litter size differences among the lines were affected by mating later in the breeding season, which typically results in higher mean litter size (Shelton and Morrow, 1965).

Ewes received some supplement on range in late autumn or early winter, depending on range conditions which varied greatly from year-to-year. One to two weeks prior to expected start of lambing and at intervals of about two weeks thereafter, ewes in late pregnancy were "bagged out", i. e. separated from the flock based on palpation of udders, and fed alfalfa hay or pellets in pens with access to shelter until lambing. The ewes in all lines were maintained, throughout most of the project, as one "drop band" until lambing; for the last eight years, they were separated by line during the immediate prelambing period to avoid the possibility of interline transfers due to mismothering.

At lambing, each ewe and her lamb(s) were placed in small ($1M^2$) pens for one to two days, then usually placed in mixing pens with 6 to 12 ewes in the barn for a few days before being transferred to the range. For much of the project, ewes with singles and twins were pastured together with some separation into different pastures by lambing date, depending on forage available. High mortality of twins under this management led to the practice in later years of separating single and twin groups into different pastures during the early suckling period. All ewes and their lambs were usually in one pasture or two or three similar pastures for several weeks prior to weaning, which occurred on one day. Lambs were weaned in mid to late May throughout most of the experiment, but due to changes in management at the station, the date was changed to early to mid-April beginning in 1985.

In all of the results reported, the year of record represents the year of the main lambing season. For example, 1962 identifies data collected for the 1961-62 production year, from mating in August 1961 to weaning in May 1962.

Data Recorded
Information recorded routinely included ewe weight at start of breeding (mating weight), lambing date, number of lambs born and weaned, and birth and weaning weights of each lamb. One hundred twenty-day weights were calculated for each lamb as:

[120 x (weaning weight - birth weight) / weaning age] + birth weight

Additional weight and fleece data were generally recorded but are not reported here. Information on ovulation rate and prenatal survival (Quirke et al., 1985; Bradford et al., 1986), milk production and body composition (Brown et al., 1987) and age at puberty (Li et al., 1992) was recorded in some years.

Statistical Analyses
Analyses were divided into two parts: 1. Least-squares analysis to report observed performance of each line, 2. Mixed model analysis to obtain estimates of phenotypic and genetic parameters, including estimates of breeding value, heritability, and genetic trends over the course of the selection experiment. Least-squares analysis (Harvey, 1979) of 120W included the fixed effects of year, sex, age of dam, and type of birth and rearing (TBR). Litter size analyses included the fixed effects of year and age of ewe. A small group of six-year-old or older ewes were combined with five-year-old ewes.

Estimates of breeding values (EBV), heritability (h^2) and other parameters, including inbreeding coefficients, were carried out using a derivative-free REML software (MTDFREML, Boldman et al., 1993). Fixed effects used in statistical models varied depending on the trait in analysis, but included year, age of the ewe or lamb, TBR of the ewe or lamb, sex of lamb, and two-way interactions. Random effects included direct effects, permanent environmental effects, and, for 120d weight, maternal effects. Heritability was calculated as the ratio of direct or direct plus maternal variance to total variance (Falconer, 1985).

Annual selection differentials for 120W were calculated as the difference between the mean of the selected animals and the mean of the line-year group from which they came, using weights pre-adjusted to a single, female, mature dam basis using multiplicative factors developed from data from this project (Lasslo et al., 1985a). These annual selection differentials were then summed to obtain cumulative selection differentials.

Selection differentials for litter size were calculated as follows. The mean number of lambs born for each year-of-birth X line cohort of ewes in each production

Table 2. Least-squares mean litter size born for control (HC), weight-selected (HW, DH) and multiple birth-selected (HT) lines by 3-year periods[1]. See table 1 for description of lines.

	HC		HW		DH		HT	
Years	N	Mean	N	Mean	N	Mean	N	Mean
63-64[2]	68	1.27	65	1.44	58	1.38	—	—
65-67	216	1.37	209	1.46	170	1.37	147	1.54
68-70	228	1.37	197	1.31	160	1.45	225	1.52
71-73	191	1.32	196	1.36	168	1.42	238	1.47
74-76	186	1.18	161	1.35	159	1.21	272	1.46
77-79	285	1.26	183	1.35	252	1.33	303	1.43
80-82	338	1.31	198	1.41	189	1.29	364	1.44
83-85	225	1.27	169	1.45	153	1.25	328	1.47
86-88	182	1.39	164	1.58	163	1.43	269	1.59
89-91	145	1.48	144	1.60	136	1.48	216	1.65
92-93[2] (early)	117	1.35	90	1.53	93	1.49	181	1.53
94-95[2] (late)	126	1.62	96	1.85	102	1.68	205	1.87
Mean intra-year CV		34.5		35.1		35.0		34.5

[1] Table values are unweighted averages of annual least-squares means. For the base population ewes (1960-64), the mean was 1.41 from 749 lambings
[2] Two years only

year was calculated, for each age group two through six years. The deviation of each ewe's record (age two through six) from the corresponding cohort mean was then calculated for each year the ewe was in the flock (all zero records—dry/barren ewes—were excluded). A mean deviation (based on one to five records) was then calculated for each ewe. The selection differential for females for a line-year was calculated as the mean of the individual deviations for all ewes lambing in that line that year. The selection differential for males was calculated as half the mean of the deviations of the dams of rams siring lambs in that year. The annual line differential was the average of the female and male differentials. Annual differentials were then accumulated. In the first two years of line HT, the ewes were from other lines, including some from groups of similar breeding but outside this experiment, so selection differentials for the initial population were not calculated.

Realized heritability was calculated by regressing the difference between selected and control line least-squares means on the difference between selected and control line cumulative selection differentials. For 120W, realized heritabilities for HT were included, although this was not the primary selection trait in that line, since some selection for 120W did occur in that line as a result of selecting rams large enough to breed as lambs. Selection differentials for litter size in HW and DH were near zero, and realized heritabilities were not calculated for these lines. For line DH, realized heritability for 120W was calculated only for the period beginning in 1978, when rams from this line were first selected from lambs raised in the Hopland flock.

The use of ram lambs in the selected lines resulted in a generation interval of one year for males in those lines. Average age of ewes at lambing was between three and four years in all lines, for an average generation interval of 2.0-2.5 years. Thus there was a minimum of 12 generations of selection.

Results

Litter Size

Mean Performance. Least squares means for litter size for the four lines, HC, HW, DH, HT, are summarized in Table 2. Since all ewes lambing in 1961 and 1962, and older ewes in the two subsequent years, were foundation stock animals, annual least squares means from these data were averaged and are reported as "base population." For subsequent years, the annual least squares means for 3-year periods were averaged and reported as a single value, to reduce number of entries in the table and the effects of annual environmental variation. Exceptions to this were the initial 2-year period, 1963-64, and the final stage, where results for November-December lambing (1992 and 1993) and February lambing (1994 and 1995) are presented separately to show seasonal effects.

Means for all lines showed quite large year-to-year variation and even the 3-year means varied appreciably. Differences due to mating season were, in general, in accord with expectation, with lower values from fall lambing and the highest recorded value for each line produced by the February lambing. Also, the differences between HT and HC and HW and HC increased in the 1994 and 1995 seasons, i. e. for the later lambing period.

Table 3. Least-squares mean 120W (kg) for control (HC), weight-selected (HW, DH) and multiple birth-selected (HT) lines by 3-year periods[1]

	HC		HW		DH		HT	
Years	N[2]	Mean	N	Mean	N	Mean	N	Mean
62-64	244	29.4	223	30.2	204	30.6	—	—
65-67	242	29.2	243	29.9	189	30.5	202	30.5
68-70	244	26.8	224	28.8	198	29.1	250	26.9
71-73	204	28.4	190	31.1	177	30.9	207	28.9
74-76	134	27.5	105	31.3	92	32.9	274	29.7
77-79	262	26.5	165	30.2	141	30.1	263	27.0
80-82	216	27.7	104	30.5	93	30.9	212	28.6
83-85	112	28.8	100	32.2	98	32.7	187	29.8
86-88	111	33.0	112	36.2	99	38.2	154	35.1
89-91	179	30.5	171	35.0	149	35.6	269	33.0
92-94	157	28.8	127	33.9	104	33.3	254	30.4
Mean intra-year CV		14.1		14.2		13.6		15.0

[1] Table values are unweighted averages of 3 annual least-squares means. For the base population (1959-61), the mean was 31.3 for 740 lambs
[2] N = Total number of lambs for the 3 years

The control group showed no evidence of negative time trend, which might have been expected with inbreeding depression; some of the higher values were recorded in the later years (not counting the high '94-95 value due to season). Intra-year coefficients of variation averaged approximately 35% in all lines.

Line HT was consistently superior to HC in litter size but the pattern is surprising; the difference between the two remained relatively constant throughout, suggesting that most of the genetic improvement resulted from the initial screening of ewes for HT. The HT-HC difference for the period 1983-1993 was .19 lambs per ewe lambing, or 14% of the mean; it averaged .25 lambs, 15% of the mean in the final two years.

Line HW results indicate a significant increase in litter size, following an initial lag of several years, eventually reaching a difference (HW-HC) of .17 lambs per lambing for the period 1983-1993; it was .23 for the final two, late-lambing seasons. Line DH on the other hand, though on average it had slightly higher litter size than HC, showed no consistent trend with time.

Estimated Breeding Values

EBVs for the four lines 1963 through 1994 are shown in Figure 1. For the most part, these show a pattern of line differences similar to that of the means in Table 2. They confirm the fact that the initial screening of ewes for HT produced a clear genetic difference; however, the EBVs show a steady, if modest, subsequent increase in genetic superiority of HT over HC, which was not as evident from the least squares analysis. The difference between HW and DH in litter size is very clear from Figure 1. From 1969 to 1990, HW increased in genetic potential for litter size at a more rapid rate than HT and reached a level at least equal to HT, .18 above HC. DH, on the other hand, remained at a level just slightly above HC.

The pattern for HC indicates a relatively stable control with mean EBVs showing a maximum range from the lowest to the highest year of less than .05. HC values were all slightly negative, i.e. mean EBVs were below the level of the base population.

Selection Differentials

Cumulative selection differentials for the four lines are graphed in Figure 2. Values for line DH begin in 1980 since sires of ewes lambing before that date were brought in from another flock.

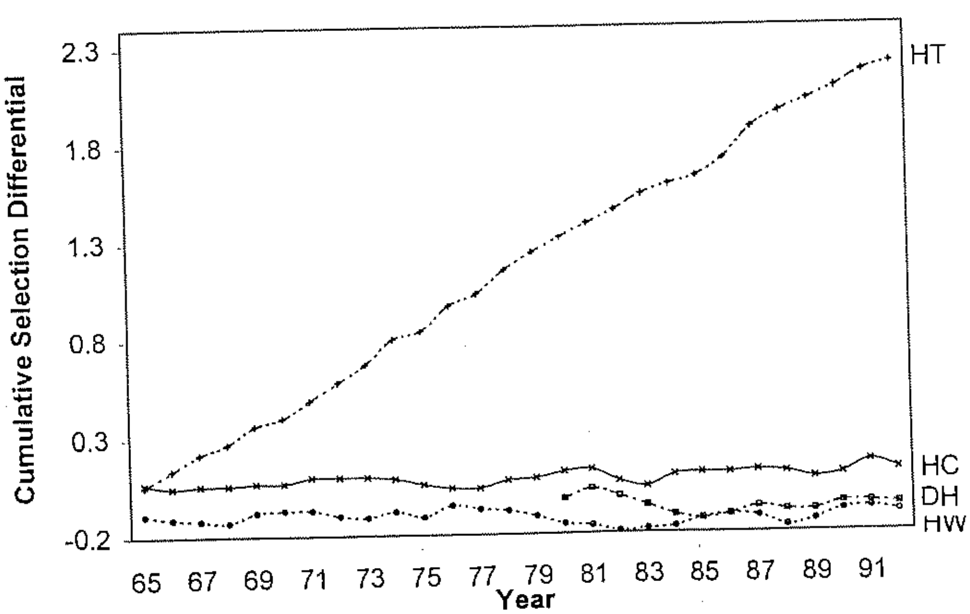
The selection differentials indicate quite steady selection pressure in line HT. They also indicate little selection for litter size in line HC or in either of the weight-selected lines. Thus, they do not explain the divergence in litter size between line HW and lines HC and DH, nor the more rapid increase in HW than in HT.

Realized heritability. The regression of HT-HC difference on difference in cumulative selection differential was .011±.027. Estimated heritability from the mixed model was .09.

120-Day Weight (120W) Mean Performance

Least squares means for 120W for the four lines are summarized by 3-year periods in Table 3. The change to an earlier weaning age in 1985 resulted in some extrapolation to obtain 120W, which resulted in an increase in the mean for all lines. However, this change did not affect the time trend in selected minus control line differences.

Figure 2. Cumulative selection differentials for litter size for four lines of sheep



The control line (HC) was relatively stable in its performance and, as for litter size, the means provide no evidence of inbreeding depression over time.

The two weight-selected lines showed a direct response to selection of about 5 kg over the course of the experiment, or approximately 17% of the original mean. Line HT had a mean above that of the control over almost the entire period of the experiment, with the final years 6-8% above the control.

All lines were consistently similar in coefficient of variation, at 14-15%, throughout the experiment.

Estimated Breeding Values

Estimated breeding values for the four lines are shown in Figure 3. As for litter

Figure 3. Estimated Breeding Values (EBV) for 120 W (kg) for four lines of sheep

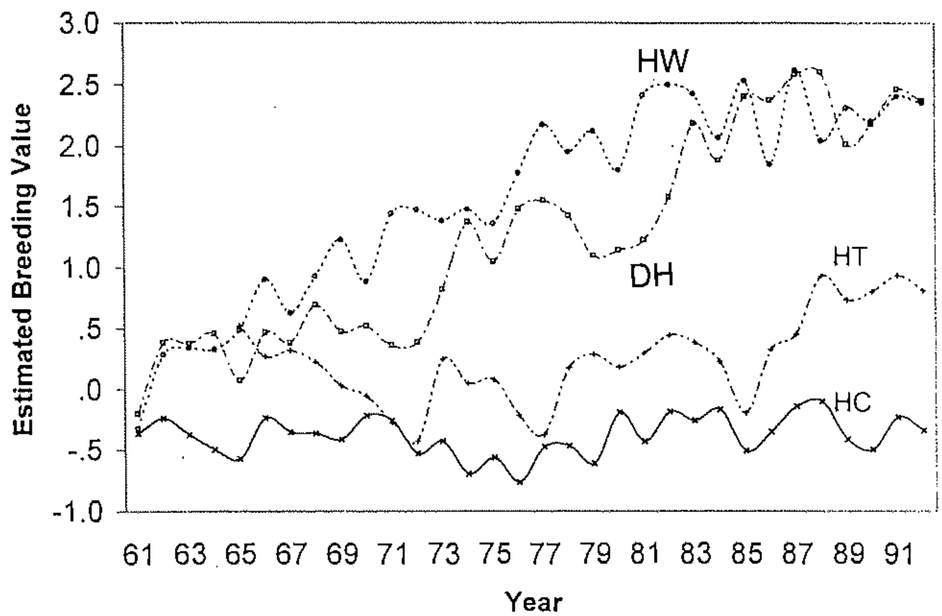
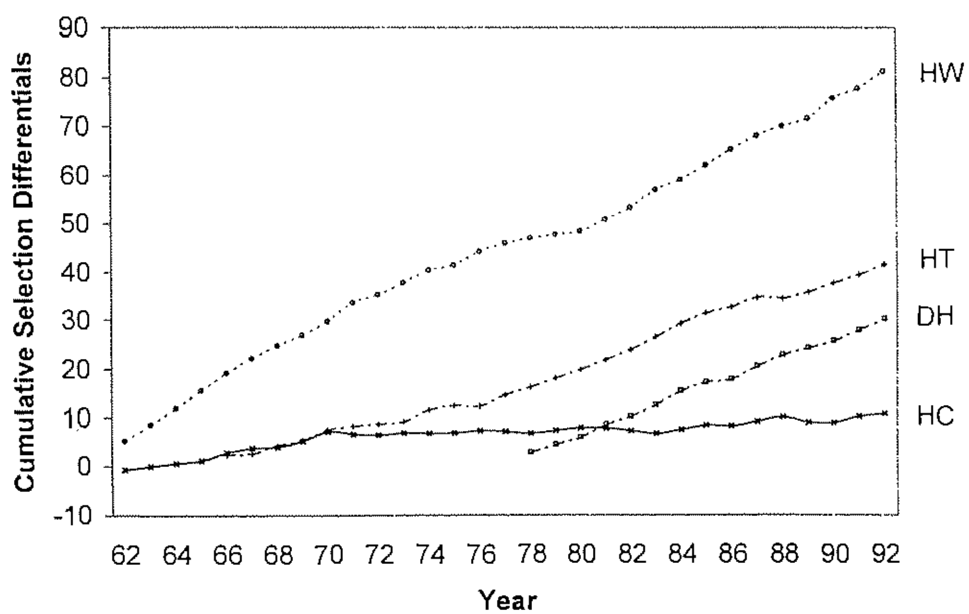


Figure 4. Cumulative selection differentials for 120 W (kg) for four lines of sheep



size, the 120W EBVs for line HC were consistently below the base population mean. The two lines selected for weaning weight diverged from the control early in the experiment and continued to do so fairly steadily for some 25 years, but there is an indication that response slowed or ceased towards the end of the experiment in line HW. Line HT, on the other hand, remained slightly above HC for approximately 20 years, then increased in EBV for 120W over the last seven years.

These trends were confirmed by linear and quadratic regression of individual EBVs on year of birth of lamb. Line DH showed a significant linear increase for 1961-80 (.157), 1981-92 (.205) and 1961-92 (.186), but no significant quadratic coefficients. Line HW showed a significant linear increase for 1961-80 (.244), but not for 1981-92 (.020). The 1961-92 linear coefficient was significant (.172), but both linear (1.219) and quadratic (-.0068) terms were significant when a quadratic term was included. Line HT, as indicated in Figure 3, showed the opposite pattern, a nonsignificant linear term (-.037) during the first period, a significant linear increase (.136) during the second period, and significant linear (-1.16) and quadratic (.0078) terms for the entire experiment.

Selection Differentials

Cumulative selection differentials averaged for sires and dams are graphed in Figure 4. (The selection practiced in DH prior to 1978, when rams came from a different location, is not shown; the point of interest here is that the slopes for lines HW and DH are approximately the same during the later period). As reported by Lasslo et al. (1985a), practically all of the selection applied was via the sires. Selection differentials in HW were actually somewhat higher in later years, so the slowing of response is not explained by a reduction in selection pressure. On the other hand, the selection differentials for 120W in line HT (secondary selection differentials) were higher in the later years of the experiment, coinciding with the observed increase in EBVs for this trait in this line.

Realized Heritability

The estimated realized heritabilities for lines HW (1962-92), DH (1978-92) and HT (1966-92) were .06±.008, .08±.037 and .05±.020, respectively. These are all substantially lower than the value of .16 from the mixed model analysis.

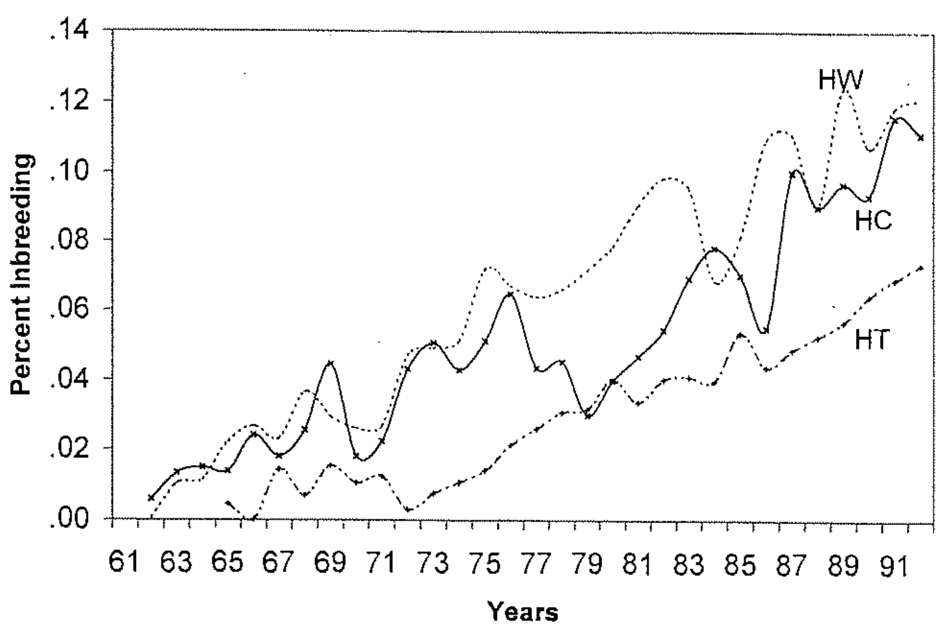
Inbreeding

Average inbreeding coefficient for lambs born in lines HC, HW and HT are shown in Figure 5. Rates were similar in lines HC and HW, reaching a level of about 12% after 30 years. As indicated earlier, performance in line HC, for either litter size or 120W, showed no measurable downward trend over the course of the experiment, indicating that the accumulation of less than .5% increase in inbreeding per year had little effect on performance.

Inbreeding rate was less in line HT than in HC or HW because the line was started later and not closed for several years. After the line was closed, the rate of increase in inbreeding was quite similar to that in the other lines.

Inbreeding values are not included in Figure 5 for line DH since rams came from a different flock for the first 17 years and we did not include data from that flock in these analyses. However, population size and mating plan in line DW, from which DH was derived, were similar to those in the Hopland lines and, as expected, the increase in inbreeding was

Figure 5. Inbreeding coefficients for three lines of sheep



similar in the first 20 years of the project (Lasslo et al., 1985a). From 1978 to 1992, the total increase in inbreeding coefficient in line DH was .06, consistent with the increases for the other lines during this period (Fig. 5).

Discussion

Substantial selection pressure was applied for the target traits throughout the experiment. Realized heritability was rather low for both traits, although potentially economically important differences were produced in each. The change in litter size was less than the average from several experiments involving selection for litter size reviewed by Bradford (1985), though within the range of results reported. Fogarty (1995) reported an average of .10 for estimates of heritability of littter size in wool breeds; Davis et al. (1998) reported an estimate of .07. Thus both estimated and realized heritability values for this trait are low, but few are as low as the realized heritability found here.

Few long-term experiments involving selection for growth rate alone have been carried out in sheep. Pattie (1965) reported a realized heritability averaging .25 from four generations of plus and minus selection for weaning weight in Merinos. The estimated heritability (.16) from the animal model in this study was higher than the realized value, and, in general, estimates for this trait are even higher. Osman and Bradford (1965) obtained estimates of .19 and .40 from the foundation population for this experiment in the two locations. Other estimates from sheep of similar breeding to those in this experiment include those of Ercanbrack and Price (1977) , who obtained values averaging .24 for three groups, and Stobart et al. (1986), a value of .28. Fogarty (1995) summarized a large number of estimates of heritability of weaning weight in sheep, and reported a mean of .33 (range .08-.41) for wool breeds. The mean was lower for dual purpose and meat breds, but still >.20.

Sheridan's (1998) review showed that realized heritability values often differ substantially from ANOVA estimates, and are more likely to be lower than higher than such estimates; 77% of realized heritabilities were lower and only 21% higher than the corresponding estimates in that review.

The realized heritabilities in this experiment and the lower difference between DH and HC than between this line and a control in the more favorable environment (Lasslo et al., 1985a), suggest that the low plane of nutrition during much of the year in the range environment where this experiment was conducted limited the expression of genetic differences. Accumulated inbreeding was similar in line HC to that in the selected lines, so inbreeding depression is unlikely to be an explanation for the less-than-expected response.

Although realized heritability for 120-day weight was low, additional indirect evidence that significant genetic improvement had been effected comes from a comparison of progeny of rams of several selected strains of range sheep. Sakul et al.(1993) reported the post weaning growth rates of progeny of five groups of rams, including two different performance selected strains of US Rambouillets, two strains of Australian Merinos, and Targhees from this project (three rams each from HW and HT). Progeny of the Targhee rams ranked first among the five groups in rate of gain.

Much of the improvement in litter size in line HT appeared to be the result of the initial screening. The HT-HC difference in EBVs for litter size of the progeny of the initial ewes was .09, while the difference at the end of 30 years of selection, with substantial selection pressure throughout (Fig.2), was only .17. Clarke (1972), summarizing results of the experiment initiated by Wallace (1964), reported a substantial increase in litter size from initial screening, followed by a 14-year period with little response, and then a large response. Line HT showed a similar pattern for the first two phases, but not for the third.

Since the initial screening involved ewes from other projects, it was not possible to calculate selection differentials for the base population of HT. Therefore the initial selection and resulting response did not contribute to the estimate of realized heritability The initial screening produced as much change as all of the subsequent selection. The initial screening involved selection of the best approximately 20% of mature ewes from several groups of similar breeding. With a standard deviation in litter size of 0.5, this would produce an estimated selection differential of about 0.7 for ewes, while that for rams would be expected to be no more and probably less. Selection differentials accumulated subsequently totalled 2.2, i.e. much more than from the initial screening. Thus if the initial selection and response had been included , the calculated realized heritability would have been higher.

A substantial response in litter size to initial screening of a large population has been reported by a number of investigators, as reviewed by Bradford (1985), but as that review also showed, substantial response in some experiments with no initial screening indicates the latter is not essential to favorable results of selection for litter size.

There is a fairly clear indication that the rate of response to selection for 120W was decreasing in line HW in the later years of the experiment. Whether this represents a true plateau or not cannot be stated from the results available. With a mean generation interval of a little over two years, the leveling off was evident by generation 10. In a pilot experiment on selection for growth rate in mice (Barria and Bradford, 1981), there was a linear increase for 20 generations, followed by no response for about 10 generations, and then further response over the next 13 generations; the effective population size was larger than in line HW. Given such results and the variability in response patterns in selection experiments generally, over time and among populations, it cannot be concluded that a true plateau had been reached in this case. Line DH showed a somewhat lower response in the middle years of the experiment and a similar total response, with no evidence of a slowing of response in the final years.

As noted in Figures 1 and 3, the estimated breeding values for line HC for both traits were appreciably below those of the base population throughout the experiment. One possible explanation for this is loss of heterosis. The rams used in 1959 and 1960 to sire the base population came from breeds of related origin but now classified as different breeds, and there may well have been some heterosis expressed by base population animals. Fifty percent of that due to effects of dominance would be lost in the progeny from intermating base population animals, i.e. the first generation of the different lines, after which the population should stabilize with regard to level of heterosis. This could explain the observed pattern of HC consistently below the base population value but stable over time.

The lack of evidence for inbreeding depression in the control line is somewhat surprising in light of the well-documented effects of inbreeding on performance in sheep (Lamberson and Thomas, 1984). In a long term experiment with mice (Barria and Bradford, 1981), an unselected control population was remarkably stable in performance, for both litter size and growth rate, over more than 40 generations during which substantial increases in inbreeding level were observed. The inference is that in closed populations not subject to artificial selection, either the slow increase in inbreeding does not cause a decrease in performance, or natural selection occurs at a level sufficient to offset the deleterious effects of inbreeding.

Correlated responses to the selection practiced are reported in a companion paper (Bradford et al., 1999) but the changes in litter size in the weight-selected lines deserve mention here. Line HW achieved a litter size essentially equal to that of line HT in the absence of any appreciable selection differentials for litter size. As shown in Figure 3, there was little increase for approximately the first ten years, and then a linear increase for about 20 years. As in line HT, the increase has been shown to be due to an increase in ovulation rate (Quirke et al., 1985). The phenotypic correlation between body weight and ovulation rate is positive (Quirke et al., 1985). The HW results suggest a strong positive genetic correlation. However, the line DH results tend not to support that; although litter size averaged slightly above that of HC, there was no detectable time trend. The ovulation rate data reported by Quirke et al. (1985) showed an unusual pattern for DH in that the ovulation rate was higher than for HC at an early season, pre-flushing measurement, but did not increase with flushing and advance of the season, as occurred in all other lines. A relatively lower responsiveness of line DH to seasonal effects is also evident in the comparison of early (1992-93) and late (1994-95) lambings (Table 2); HW and HT had litter sizes higher by .32 and .34 in February than in November/December, whereas DH increased by only .19.

The higher coefficient of variation for litter size than for weaning weight is well documented by these results. CV's for litter size were 34 to 35% in all lines, while those for 120W were 13.6 to 15%. This permitted a percentage response to selection for litter size nearly as great as that in 120W, in spite of lower realized h^2 and the fact that litter size is measurable in females only.

Implications

Realized heritability for both litter size and 120-day weight was lower than most ANOVA estimates for these traits, including estimates from these data. In spite of this, economically significant improvement was made in each trait. A much higher coefficient of variation in litter size permitted a percentage increase in mean litter size nearly equal to that in 120-day weight, in spite of lower realized heritability and the sex-limited nature of the trait. Selection for either trait in a range environment improved performance for that environment.

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Selection for Weaning Weight or Litter Size in Range Sheep
II. Correlated Responses and Effect on Productivity[1]

G. E. Bradford[2], H. Sakul[3], and M. R. Dally

Abstract

Mating weights, ewe fertility, lamb survival and total 120 d weight of lamb per ewe lambing are reported for an unselected control line (HC) and for lines selected for either adjusted 120 d lamb weight (HW and DH) or litter size (HT). Lines HW and DH achieved mean ewe mating weights about 8 kg above HC, for a greater absolute increase than the approximately 5 kg direct response in 120d lamb weight. HT increased little in ewe weight. Fertility was consistently highest in HT, while HW and DH were slightly below HC. Lamb survival was consistently highest in HC, followed by HT, HW and DH. For both fertility and lamb survival, DH, in which rams were selected in a different environment for the first half of the experiment, was consistently lowest. Total 120 d weight of lamb per ewe lambing was highest in HW, as a result of both direct response and a correlated increase in litter size, followed by HT and DH. Considering all traits, it was estimated that lines HW and HT weaned 11 to 12% more lamb per unit ewe metabolic weight than HC. This is an economically significant increase, although relatively small for more than 30 years of selection. The results indicate that response to selection for performance traits is slow in a nutritionally limiting environment, but that useful improvement can be made. The results (for weaning weight) also suggest that selection under range conditions is more effective in improving performance in that environment than selecting in an environment where heritability is higher and then transferring the improved stock.

Key Words: Sheep, selection, litter size, weaning weight, correlated response, ewe productivity

Introduction

Selection for production traits is a recommended means of improving genetic potential for productivity in sheep, but the net impact on flock productivity of changes in individual traits depends not only on the magnitude of the direct response but also on the direction and magnitude of any correlated changes.

A long-term experiment involving selection for litter size or for adjusted 120 d weaning weight (120W) in Targhee sheep in a range environment produced direct responses of 15% to 17% above the control population mean for each of the traits (Sakul et al.,1999). While these amount to less than a 1% increase per year, the cumulative increases represent the potential for a substantial increase in flock productivity. In this paper, we report correlated changes in mature ewe weight as an indicator of feed requirements, in fertility and lamb survival as indicators of fitness, and in weight of lamb weaned per ewe in the flock as a measure of overall productivity.

Materials and Methods

The environment, animals and methods are described in a companion paper (Sakul et al., 1999). Briefly, a population of whiteface range sheep similar to the Targhee breed in proportion of finewool and longwool inheritance was divided at random into lines selected for weaning

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weight (HW and DH), multiple births (HT) and an unselected control (HC). These were maintained as closed lines from 1961 through 1995, except that line HT was created by screening aged ewes, from the other lines in this project and additional groups of similar breeding, for individuals with high multiple birth production, beginning in 1963 and continuing for several years before it was closed.

Sheep in all lines were maintained as one flock grazing annual grassland range each year throughout the experiment, except for a two-week flushing period (as one group) and a 35-day breeding season when they were fed in single-sire mating pens. Teaser rams were with the ewes during the flushing period. Breeding rams were introduced in early August (7th to 10th) from 1960 through 1990. To test for differences between lines in response to seasonal effects, the breeding season was changed to June 20 to July 27 in 1991-92 and 1992-93, and to September 15 to October 20 for 1993-94 and 1994-95. The ewes were also fed in the barn from one to two weeks prior to lambing until a few days after lambing and supplemented on range in late summer, autumn and winter as needed, depending on range conditions which varied greatly from year to year.

Matings to produce linecross lambs were made in several years, using random samples of ewes and the same rams as used for within line mating. Data from these ewes on mating weight, fertility and litter size born were included in summaries for the line to which the ewe belonged, since there was no evidence these variables were affected by line of service sire. Data from linecross matings were excluded from analyses of lamb viability, individual 120 d weight and total 120 d weight of lamb per ewe.

In 1980 and 1981, one male lamb was removed at birth from each ewe with twins including at least one male lamb, for an artificial rearing study; where there was more than one male, the lamb removed was chosen at random. Data from those two years were therefore excluded from analyses of viability and total 120 d weight of lamb per ewe.

Traits reported in this paper include ewe mating weight, fertility, lamb survival and total 120 d weight of lamb weaned per ewe per year.

Statistical Analyses

Analyses were divided into two parts: 1. Least-squares analysis to report observed performance of each line, 2. Mixed model analysis to obtain estimates of phenotypic and genetic parameters, including estimates of breeding value, heritability, and genetic trends over the course of the selection experiment. Least-squares analysis (Harvey, 1979) of ewe mating weight included the fixed effects of year, age of ewe, type of birth and rearing (TBR) of the ewe, and ewe agexTBR interaction. Ewe fertility analyses included the fixed effects of year and age of ewe, and an interaction term between these two traits. Lamb survival analyses included year, age of ewe, type of birth, and the two-way interactions among these variables. Finally, analyses of total 120 d weight per ewe lambing considered fixed effects of year and age of the ewe, as well as their interaction. Methods and random effects used in the estimation of breeding values (EBV), heritability (h^2) and other parameters, including inbreeding coefficients and realized heritabilities, were explained in the companion manuscript (Sakul et al., 1999).

Results

Ewe Mating Weight

Estimated breeding values for ewe weight at mating for the four lines are graphed in Figure 1. Line HC declined initially, possibly due to loss of heterosis as discussed by Sakul et al. (1999). It did recover some of the loss in later years and was fairly stable for the last 10-12 years at a value 2-3 kg below the base population level. Selection for weaning weight resulted in a correlated increase in mature ewe weight in the two weight selected lines, which prevented the initial decline observed in line HC and resulted in a deviation of 8 kg from line HC by the end of the experiment. The increases in line HW and DH were essentially parallel throughout the experiment, with no evidence of a plateau in HW as suggested by the direct response in 120W (Sakul et al., ——). The increase in HW and DH represents about 15% of the HC mean, proportionately nearly as large as the 17% direct response in 120W. Line HT also declined initially but stabilized at a level approximately 1.3 kg (2.5%) above HC.

Assuming maintenance energy requirements are proportional to wt $^{.75}$, ewes from the weight-selected lines would require approximately 11% more feed than control ewes, while HT ewes would require about 2% more.

Least squares means for mating weight by age and by type of birth and rearing of the ewe for the four lines are presented in Table 1. The ages refer to the age at lambing; actual ages when weights were recorded would be 5 to 6 months less. Mating weight increased continuously from that at 2 years to ≥5 years, averaging 8, 15 and 18%, respectively, more than at first mating for ewes aged 3, 4 and ≥5 years.

Ewes born as twins weighed significantly less than singles on average over their lifetime, with the proportionate difference similar in all lines. To investigate whether ewes born as twins ever achieved the same weight as singles, a second analysis, including age x TBR (S/S, T/S, T/T) interaction, was carried out. In all lines, ewes born and raised as twins remained significantly lighter in weight than singles; the interaction was significant ($P=.05$) only in line HC. The difference in weight between singles and twins raised as twins (T/T) ranged, across lines, from 3.1 to 3.8 kg at first mating and from 1.7 to 3.0 kg at fourth and later matings. Twins raised as singles (T/S) were intermediate between S/S and T/T in all cases.

The proportions of breeding ewes born as twins (Table 1) for the four lines are in general accord with the average difference among the lines in litter size (Sakul et al., 1999), with HT highest, DH only slightly above HC, and HW intermedi-

Figure 1. Estimated breeding values for ewe mating weights (kg) for four lines of sheep

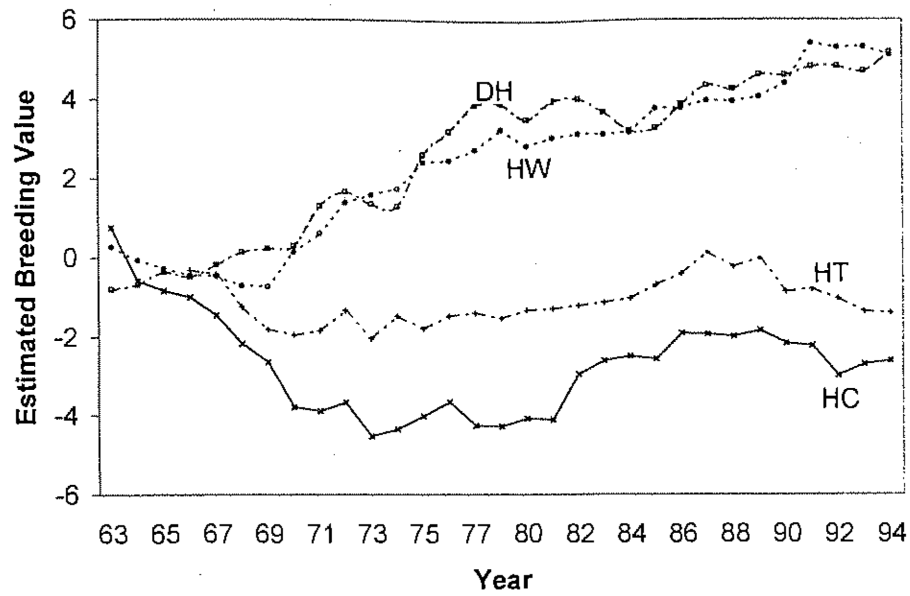


Table 1. Effects of age and ewe type of birth and rearing on ewe mating weight (kg) in control (HC), weight-selected (HW, DH) and multiple birth-selected (HT) lines of sheep

Age of ewe at lambing (yr)	HC		HW		DH		HT	
	No.	Weight	No.	Weight	No.	Weight	No.	Weight
2	631	49.0	592	53.7	532	54.7	809	49.9
3	541	52.8	499	57.8	445	58.0	629	54.5
4	421	56.8	392	61.6	355	61.9	478	58.7
≥5	735	58.1	604	62.6	553	63.4	866	59.5
Ewe type of birth and rearing								
11	1253	55.2	979	60.3	991	61.0	1015	56.8
21	163	54.5	267	58.7	248	60.0	291	55.8
22	918	52.8	891	57.8	646	57.5	1476	54.3
% of all ewes born as twins	46.3		55.5		48.2		63.5	
% of twin ewes raised as singles	15.1		23.1		27.7		16.5	

ate. HW attained a litter size equal to that of HT at the end of the experiment but was less prolific in the earlier years. The higher proportion of ewes born twins which were raised as singles in DH and HW are consistent with differences among the lines in lamb viability reported below.

Ewe Fertility

Fertility, i.e. ewes lambed (EL) /ewes present at lambing (EPL), varied substantially in all lines over the years, but in general showed a declining trend with time. A possible explanation for the trend was a decrease in forage available per animal due to an increase in effective stocking rate on the station. Other aspects of the environment may also have been involved.

Linear and linear plus quadratic regressions of EL/EPL on year were calculated for each line for the period 1963-1991. Data from the final four years, when mating season differed, were not included. None of the quadratic coefficients was significant, so only the linear regression analysis results are presented (Table 2). All lines declined , with the greatest decline (P<.01) in line DH, consistent with the earlier results reported by Lasslo et al. (1985b). Compared to line HC, fertility in line DH declined approximately 6% over the 29-year period.

Table 2. Regression of fertility (EL/EPL) on year (1963-91) for control (HC), weight-selected (HW, DH), and multiple birth-selected (HT) lines of sheep

Line	Regression ± SE	Intercept
HC	-.0023 ± .0007 **	.94 ± .012
HW	-.0017 ± .0012	.92 ± .020
DH	-.0044 ± .0014 **	.96 ± .024
HT	-.0018 ± .0010	.94 ± .017

** P<.01

The lines did not differ appreciably in fertility when matings were in June and July. In 1991-92, an outbreak of blue tongue lowered fertility in all lines, to 79 to 86%. In 1992-93, 91 to 94 % of the ewes in the different lines lambed in November and December, indicating good early season breeding performance in these stocks. Estimated breeding values for fertility are presented in Figure 2. The heritability estimate from this analysis was only .01, so the EBVs are low. In spite of this, the lines differentiated, with HT highest, followed in order by HC, HW and DH. This ranking of the lines was maintained consistently for approximately 20 years.

Lamb Survival

Linear and linear plus quadratic regressions of lamb survival on year were calculated for each line X type of birth (singles, multiples) group. The linear coefficients are presented in Table 3. Survival of single lambs declined in all lines, but the decline was significant only in line HW (P<.05). None of the coefficients was significant for multiple birth lambs, although the decline was appreciable in line DH. The intercepts indicate a difference in survival rate between singles and multiples averaging about

Figure 2. Estimated breeding values for % fertility for four lines of sheep

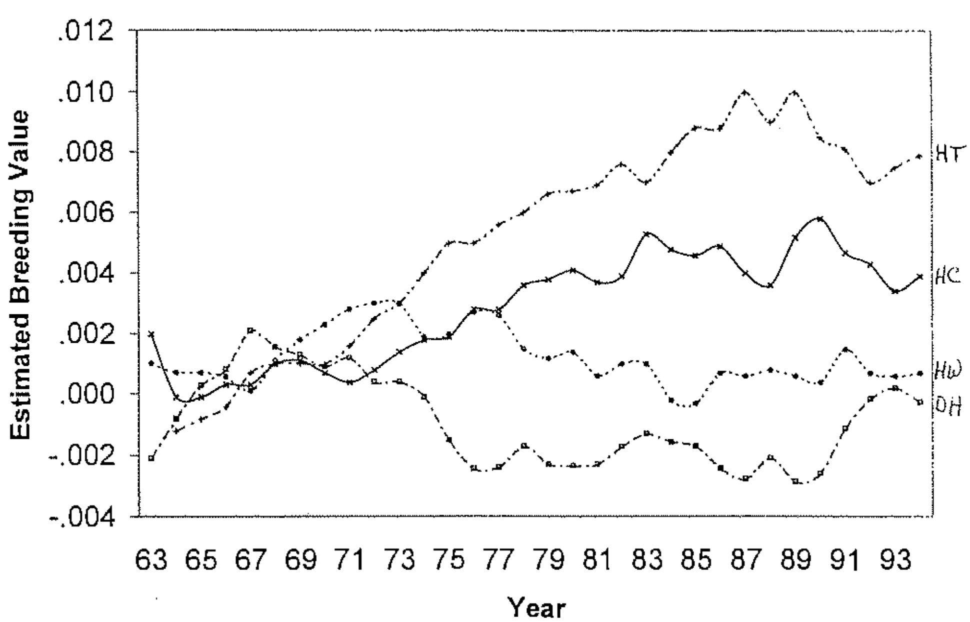
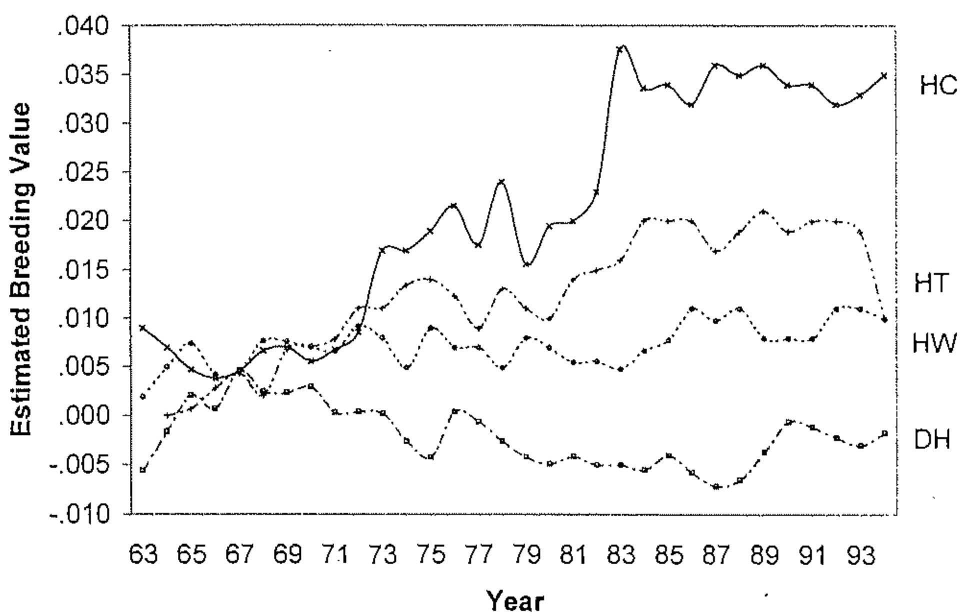


Table 3. Regression of lamb survival rate on year (1961-91) for control (HC), weight-selected (HW, DH), and multiple birth-selected (HT) lines of sheep

	Singles		Multiples	
Line	Regression ± SE	Intercept	Regression ± SE	Intercept
HC	-.0010±.0014	.86±.026	-.0011±.0026	.76±.048
HW	-.0033±.0014*	.92±.025	-.0007±.0023	.76±.041
DH	-.0030±.0020	.90±.036	-.0026±.0029	.75±.054
HT	-.0001±.0024	.86±.046	.0035±.0019	.72±.037

[1] * P<.05

Figure 3. Estimated breeding values for % lamb survival for four lines of sheep



14%.

The quadratic coefficients were not significant except for DH multiples, for which the equation was $Y=.91(\pm.073) - .030(\pm.010)X + .0008(\pm .0003)X^2$. This suggests that there was some recovery in later years from the low survival characteristic of this line prior to 1980 reported by Lasslo et al. (1985b).

The EBVs for survival are shown in Figure 3. As for fertility, estimated heritability was low (.02), but the lines differentiated, and maintained a consistent ranking (HC, HT, HW, and DH lowest) for the last two-thirds of the experiment. These values also indicate that the observed decline in overall lamb survival rate was environmental. The results suggest that there was actually some genetic improvement in this aspect of fitness in line HC and possibly in line HT.

Total 120 d Weight Per Ewe Lambing

Total 120W of lamb weaned per ewe lambing in the four lines is summarized by 3-year periods in Table 4. Data from 1980 and 1981 were omitted for this trait as explained earlier, and data from the next four years were combined for the next period mean. The effect on individual 120W of the change in weaning age from 1985 on (Sakul et al, 1999) is evident in this trait also.

Selection for weaning weight or for multiple births resulted in an increase in total 120W of lamb weaned per ewe. Over the final six years of the experiment, lines HW, DH and HT average 22%, 17% and 14%, respectively, above line HC. The increase in HW reflects an increase in both individual weaning weight and number of lambs weaned, i.e. both direct (growth rate) and correlated (litter size) responses. In DH and HT, the increase in total litter weight is fully accounted for by direct response, i.e. by the increase in weaning weight in DH and litter size in HT.

Table 4. Total 120 d weight (kg) of lamb per ewe lambing per year for control (HC), weight-selected (HW, DH) and multiple-birth selected (HT) lines by 3-year periods[1]

	HC		HW		DH		HT	
Years	N	Mean	N	Mean	N	Mean	N	Mean
63-64[2]	62	36.9	57	39.3	55	38.8	—	—
65-67	181	37.2	187	38.0	155	37.9	132	39.4
68-70	185	32.0	157	35.7	140	37.9	162	35.1
71-73	144	35.2	137	39.7	133	38.1	151	37.0
74-76	124	32.6	91	38.0	88	37.2	203	39.6
77-79	208	33.7	143	37.4	124	36.8	221	33.8
82-85[3]	171	35.6	124	39.8	117	37.8	224	39.6
86-88	79	44.0	94	51.1	77	49.4	114	47.8
89-91	137	40.1	127	49.9	114	46.7	193	46.3
92-94	142	36.1	114	43.2	108	42.6	226	40.6
Mean intra-year CV	30.3		30.7		29.4		32.3	

[1] Means are unweighted averages of annual least squares means
[2] Two years
[3] See text

Figure 4a. Estimated breeding values for total 120 d weight (kg) per ewe lambing for four lines of sheep

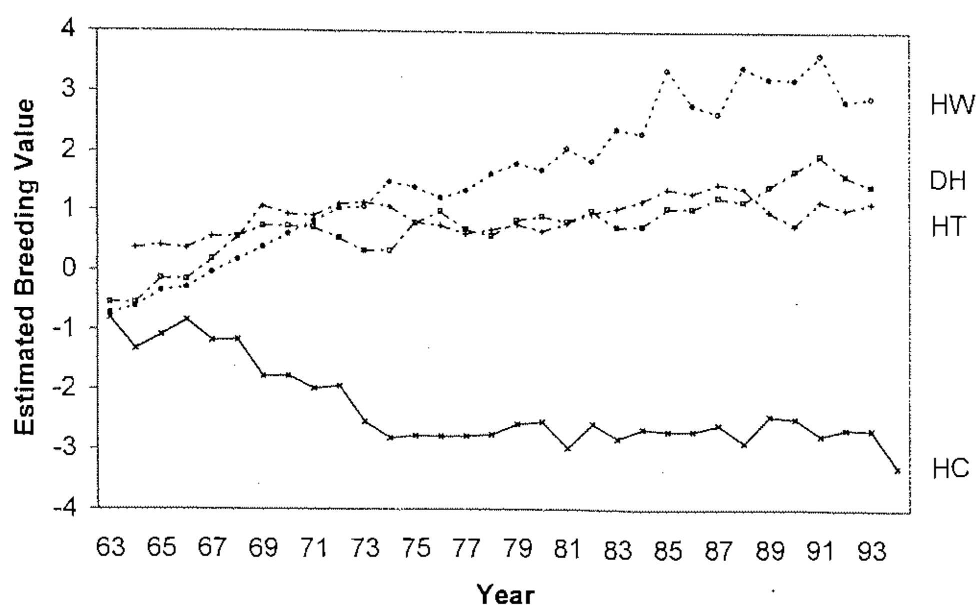
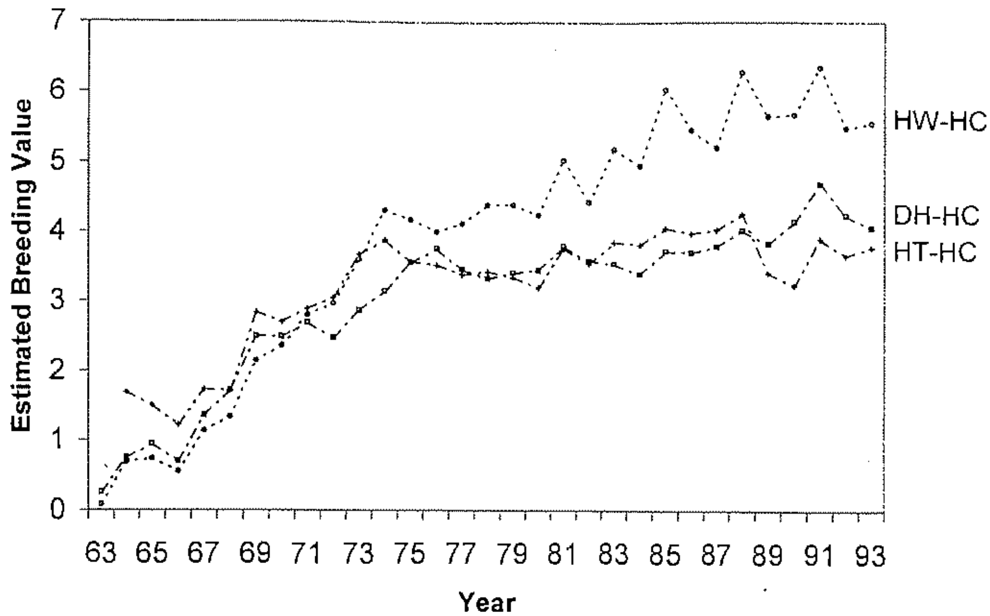


Figure 4b. Estimated breeding values, deviated from control line, for total 120 d weight (kg) per ewe lambing for three lines of sheep



There were quite large fluctuations in the means due to environmental factors, including the effect of a different weaning age from 1985. The coefficient of variation was in the region of 30% for all lines, slightly more than double that for individual lamb 120 d weight but a little less than that for litter size (Sakul et al., 1999). Estimated breeding values for the four lines are shown in Figure 4a and deviations of the three selected lines from HC in Figure 4b.

The EBVs for line HC decreased by more than 2 kg over the first 10-12 years of the experiment and were stable thereafter. A decrease over the first generation in two of the component traits, litter size and individual 120 d weight, was reported by Sakul et al. (1999), compatible with loss of heterosis when base population animals, which included some breed crosses, were intermated. An explanation for the longer period of decline in total 120 d weight is less obvious.

The selected lines increased quite steadily in this measure over the entire course of the experiment. Because of the decline in HC, the increase in the deviations was considerably greater in the earlier years of selection.

Discussion

The decline in fertility in all lines was apparently due to environmental factors, since the breeding values for this trait increased in lines HC and HT and changed little in HW. A decline in mean fertility in line DH occurred during the latter part of the period when rams were imported from the more favorable environment (Lasslo et al., 1985b). After rams raised in the range flock were used, performance of this line stabilized for several years, and may have improved slightly at the end.

The general pattern of line differences in lamb viability was similar to that for ewe fertility, i. e. with evidence of a negative environmental trend, low heritability, but with the lines maintaining the same ranking through a period of nearly 20 years. Again, the two weight selected lines were slightly but consistently lower than HC and HT. However, for lamb viability, line HC was consistently best, while for fertility line HT was best.

The lower mean fertility and lamb viability in lines DH and HW suggests that selection for growth rate has an adverse effect on fitness, at least in this environment, although the absolute differences were fairly small. A decrease in fitness did not occur in the weaning weight selection experiment reported by Pattie (1965). However, that experiment was for four generations, while in the present experiment, selection was practiced for more than 12 generations, with the differences among lines not clearly established until after the first third of the experiment (Figures 2 and 3).

Total weight of lamb per ewe lambing increased in all three selected lines relative to that of the control, with the greatest increase in line HW in which both weaning weight and prolificacy increased. The reduction in lamb livability in the weight lines was not enough to offset the increase in individual lamb weight.

The results presented are on the basis of ewes lambing. If an estimate of the differences in fertility is incorporated, the advantage of line DH over HC would decrease to about 12%, while the HW – HC and HT – HC differences, 22 and 14%, would change little. Maintenance energy requirements based on ewe mating weights were estimated to be about 11% higher for HW and DH, and 2% higher for HT, than for HC. On this basis HW and HT ewes would wean 11 to 12% more lamb per unit of ewe metabolic body weight, whereas DH, with similar individual lamb weaning weight to HW but somewhat lower fertility, litter size and lamb viability, would differ little from the control in this measure of output/input. The increase of 11-12% in total 120 d weight of lamb per unit of ewe metabolic body weight in lines HW and HT represents an economically important gain, though a modest one for more than 30 years of selection. The reason for the small gain is obviously the low realized heritability for both weaning weight and litter size. For both traits, realized heritability was less than half the mixed model estimates of heritability from these data, i. e. .09 for litter size and .16 for 120 d weight. The latter, in turn, are towards the low end of the range of previously reported estimates for these traits. An important question is why are these estimates so low.

There is evidence from different measures of performance that this location represents a difficult environment. The difference in average survival between singles and twins, 14%, is large. The fact that the lighter weight of twins persists throughout their productive life is unusual, and suggests that twinning handicap may be an important factor in the less-than-expected response. The difference in mating weight (11 kg = 21%) between ewes of the same breeding at Davis and at Hopland (Lasslo,1982) also indicates a low plane of nutrition at Hopland.

Our hypothesis is that in an environment where plane of nutrition is low much of the year, the animals do not have enough nutrients to express their genetic potential for growth and prolificacy. This does not explain the difference between estimated and realized heritability, but could contribute to low estimates of heritability. Evidence for an effect of environment on heritability of 120W comes from earlier data from this project. In an analysis of data from the base population, Osman and Bradford (1965) obtained paternal half sib estimates of heritability of .40 and .19 for the Davis and Hopland flocks respectively. Realized heritability from parallel selection was much lower than the paternal half-sib estimate in both flocks, but was higher (.17 vs. .07) in the more favorable environment (Lasslo et al., 1985a). The further results reported here confirm the low realized heritability for 120W in the range environment, and indicate a lower realized heritability for litter size than reported in most experiments.

A second question is whether there are means of circumventing this low heritability. An obvious approach, suggested by Hammond (1947) is to select in an environment permitting full expression of the trait of interest, followed by transfer of the improved stock to the environment of use. Hammond cautioned that this was advised only where the improved stock is adequately adapted to the latter conditions. Few experiments with economic species have been conducted to test this approach. While conclusions from a selected line which was not replicated should be made with caution, the results from line DH in this project are not encouraging for this approach. Not only was the greater genetic superiority obtained by selection in the more favorable environment not expressed under range conditions, but fitness of the line was appreciably inferior to that of a line selected under range conditions. At the least, the results provide no encouragement for use of this approach to improve genetic potential in the more stressful environment.

A recent paper reporting the results of selection for total weight of lamb weaned per ewe (Ercanbrack and Knight, 1998) indicates that such selection was very effective in increasing total productivity. Realized heritability was not estimated in that study, but genetic improvement from 0.9 to 2.5% per year in four different breeds was reported. The improvement in total weight of lamb weaned per ewe was attributable to improvements in prolificacy, lamb survival, lamb weaning weight, ewe fertility and ewe viability, in that order. The annual gains in litter weight weaned were substantially higher than for any of the lines in this experiment, and the percentage response higher than that from the single trait selection in the present experiment. In addition to the different selection criteria, a number of differences between the environments could have contributed to this difference in response. The higher and more stable level of nutrition, particularly during pregnancy and early lactation, for the flock reported on by Ercanbrack and Knight (1998) than existed for the present experiment, is believed to be an important contributing factor.

Implications

Improvement in genetic potential for performance traits, in this case weaning weight and prolificacy, can be made by selecting for them in a relatively stressful environment. Improvements in the component traits results in an apparent increase in efficiency of production. The response in the range environment was less than predicted by previously estimated heritabilities, from this or other studies, for both traits, and for the trait tested, less than in a more favorable environment. Although realized heritability was low in the range environment, the limited evidence available suggests that selection in that environment will result in as much genetic gain in the selected trait, and in superior fitness, compared to selection in a more favorable environment and transfer of the improved stock, i. e. that selection should be in the environment of use.

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Effects of Limited Concentrate Intake Following Forage on Subsequent Performance of Lambs Consuming Concentrate[1,2]

A. L. Goetsch[3,4] and G. E. Aiken[5]

Summary

Forty-eight wethers (9 months of age; 28.6 ± 0.40 kg initial body weight) were used to determine effects of a short period of restricted intake of an 80% concentrate diet following ad lib intake of forage on subsequent performance when consuming concentrate ad lib. Treatments were ad lib intake of concentrate for 14 weeks (AC); restricted intake of concentrate for 8 weeks followed by 6 weeks ad lib intake of concentrate (LC); ad lib intake of long-stemmed alfalfa hay for 8 weeks followed by 6 weeks ad lib intake of concentrate (F); and 6 weeks ad lib intake of alfalfa followed by 2 weeks restricted intake of concentrate then 6 weeks ad lib intake of concentrate (F-LC). Total dry matter intake in weeks 9-14 was 1571, 1511, 1443 and 1583 g/day for AC, LC, F and F-LC, respectively. Body weight gain was greatest ($P < 0.05$) for AC in weeks 1-6 (277, 75, 53 and 50 g/day); greatest for AC and least for F-LC ($P < 0.05$) in weeks 7-8 (230, 124, 154 and 27 g/day); and greater ($P < 0.05$) for LC and F-LC than for AC and F in weeks 9-14 (191, 274, 178, and 289 g/day for AC, LC, F and F-LC, respectively). Protein accretion in weeks 9-14 was similar among treatments, although empty body weight gain (172, 252, 204 and 262 g/day) and fat accretion (84, 151, 115 and 168 g/day for AC, LC, F and F-LC, respectively) were greater ($P < 0.05$ and 0.07, respectively) for LC and F-LC than for AC and F. In conclusion, growing phase ad lib intake of forage may affect later performance when concentrate is consumed ad lib differently than restricted intake of concentrate, and a period of limited concentrate intake following ad lib intake of forage could offer potential to improve later performance.

Key words: sheep, forage, growth

Introduction

High-forage diets are often consumed ad lib in a growing phase, followed by ad lib intake of concentrate-based diets during finishing. However, visceral organ energy use relative to absorbed energy is greater with ad lib intake of forage-based diets than with limited or ad lib intake of concentrate (Goetsch, 1998). Carryover effects in finishing of previous growing phase feeding system have not been studied extensively. In this regard, Sainz et al. (1995) observed lower live weight gain and efficiency of feed utilization during finishing for beef steers that previously consumed forage ad lib compared with steers given a restricted quantity of concentrate. Liver and stomach protein mass at the end of the growing phase were greater for steers that consumed forage ad lib than for those receiving a limited amount of concentrate (Sainz and Bentley, 1997), which suggests elevated energy use by visceral organs and less nutrients available to other tissues for a portion of the finishing period. If the length of time or magnitude of such carryover effects is appreciable, a short period of limit-feeding concentrate after growing phase ad lib intake of forage might be of benefit. This could avert or lessen high energy use by visceral organs during finishing due to prior forage consumption, and thereby increase nutrients available to peripheral tissues. Hence, the objective of this experiment was to determine effects of a short period of restricted intake of a concentrate diet following ad lib intake of forage on

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2 Mention of a trademark or proprietary product in this paper does not constitute a guarantee or warranty of the product by the USDA or the ARS and does not imply its approval to the exclusion of other products that also may be suitable.

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subsequent performance when consuming concentrate ad lib.

Materials and Methods

Animals

Forty-eight wethers (9 months of age; 28.6 ± 0.40 kg initial body weight; 16 St. Croix and 32 St. Croix x Romanov) were used in the 14-week experiment. Wethers had been weaned at approximately 75 days of age and had grazed moderate-quality grass pasture until initiation of the trial. Vaccination for Clostridium organisms (Clostridium chauvoei, septicum, novyi Type B, haemolyticum, tetani and perfringens Types C and D) and treatment with Ivomec® (Merck & Co., Rahway, NJ) occurred at weaning; lambs were again treated with Ivomec® at the beginning of the experiment. Wethers were allotted to eight groups for similar body weight and variation in body weight within group, with two St. Croix and four St. Croix x Romanov per group. Each group was placed in a concrete, partially covered 3 x 12.2 m pen and randomly assigned to the four treatments.

Dietary Treatments

Treatments were ad lib intake of an 80% concentrate diet for 14 weeks (AC); restricted intake of concentrate for 8 weeks followed by 6 weeks ad lib intake of concentrate (LC); ad lib intake of forage (i.e., small square bales of long-stemmed alfalfa hay) for 8 weeks followed by 6 weeks ad lib intake of concentrate (F); and 6 weeks ad lib intake of forage followed by 2 weeks restricted intake of concentrate then 6 weeks ad lib intake of concentrate (F-LC; Table 1). Weeks 1-8 are referred to as a growing period and weeks 9-14 as a finishing period. Alfalfa hay, when fed, was available free-choice in self-feeders, and hay present in feeders at 2-week intervals was weighed and discarded. Ad lib intake of concentrate was achieved by offering at 110% of consumption on the preceding few days, with refusals weighed and discarded daily. Transitions from forage to the concentrate diet or from restricted to ad lib intake of concentrate were made by stepwise daily increases, of equal magnitude over a 1-week period, in concentrate offered until the desired level was achieved; if being fed previously, hay was removed when consumption became negligible, which was after 1 week for F-LC. The level of the concentrate diet of-

Table 1. Forage and concentrate-based diet composition (% of dry matter).

Item	Alfalfa hay	Concentrate-based diet
Ingredient		
Ground corn		64.073
Cottonseed hulls		10.000
Dehydrated alfalfa pellets		10.000
Soybean meal		4.400
Fish meal		2.750
Soybean oil		2.500
Molasses		2.500
Blood meal		2.200
Calcium carbonate		0.800
Urea		0.500
Sodium chloride		0.180
Trace mineral premix[a]		0.050
Vitamin premix[b]		0.030
Bovatec® 68		0.017
Composition		
Crude protein	16.2	16.8
Ash	9.8	6.2
Neutral detergent fiber	56.9	
Acid detergent fiber	41.4	
Acid detergent lignin	9.1	
Cellulose	31.2	
Hemicellulose	15.5	
IVDMD[c]	65.9	

[a]Contained at least 12% Zn, 10% Fe, 8% Mn, 1.5% Cu, 0.3% I, 0.1% Co and 0.02% Se (air-dry basis).
[b]Contained at least 8.8 million IU of vitamin A, 1.8 million IU of vitamin D_3 and 1,100 IU of vitamin E per kg (air-dry basis).
[c]In vitro dry matter digestibility; 48-hour incubation with ruminal fluid; neutral detergent fiber was the end-point measure.

fered for LC and F-LC was chosen to achieve live weight gain similar to that with ad lib intake of forage, based on DM intake for F (weeks 7-8) or F and F-LC (weeks 1-8) and NRC (1985) feedstuff net energy concentrations. Dry matter intake for LC-in weeks 1-6 averaged 70% of ad lib intake of forage for F and F-LC and 53% of ad lib intake of concentrate for AC in weeks 1-8. The initial feeding rate of forage for LC as a percentage of forage intake by F and F-LC was slightly less than this average of 70% in weeks 1-6, being increased after week 2 because of slightly less than expected live weight gain. There were no apparent digestive or metabolic disturbances, although one wether died (AC) in week 13 from urinary calculi.

Measures

Feed samples were collected weekly and ground to pass a 1-mm screen. Hay was analyzed for DM, Kjeldahl nitrogen (AOAC, 1984), neutral detergent fiber, acid detergent fiber, acid detergent lignin and in vitro dry matter digestibility (filter bag technique; ANKOM Technology Corp., Fairport, NY). Cellulose was determined as the loss in weight upon sulfuric acid treatment and hemicellulose as the difference between neutral and acid detergent fiber concentrations. Samples of the concentrate diet were analyzed for DM, ash and nitrogen.

Wethers were weighed unshrunk every 2 weeks of the experiment until the end of week 8, for possible adjustments of the level of restricted intake, and after week 14. Following body weight determinations after 8 and 14 weeks, wethers were shrunk (feed and water were withdrawn for approximately 24 hours) to estimate body composition via urea dilution, as described by Galloway et al. (1996). Empty body weight (EBW) was estimated by weighing immediately after sampling. Urea was infused at 162.5 mg/kg BW, and urea space (US) was calculated as urea infused/change in serum concentration before infusion and at 12 min. Water and fat in the empty body (EBH_2O and EBFAT, respectively) were calculated with regressions presented by Poland (1991). The equation for kg EBH_2O was 7.86 + (0.259EBW in kg) + (0.195US in kg), and that for kg EBFAT was -8.92 + (0.625 EBW in kg) - (0.275US in kg). Percentages of protein and ash in the empty body (% EBPRO and % EBASH, respectively) were estimated as described by Reid et al. (1968). The equation for % EBPRO

Table 2. Dry matter intake by wethers in a 14-week growing-finishing period.

Week	Item	Treatment[a] AC	LC	F	F-LC	SE
		g/day				
1-6	Forage			1127	1131	
	80% concentrate diet	1465	791			
	Total	1465[d]	791[b]	1127[c]	1131[c]	29.2
7-8	Forage			1216	398	
	80% concentrate diet	1707	893		741	
	Total	1707[d]	893[b]	1216[c]	1139[b]	41.0
9-14	Forage			72		
	80% concentrate diet	1571	1511	1371	1583	61.6
	Total	1571	1511	1443	1583	62.5
7-14	Forage			359	100	
	80% concentrate diet	1605	1356	1028	1373	
	Total	1605	1356	1386	1472	56.0
1-14	Forage			688	542	
	80% concentrate diet	1545	1114	587	784	
	Total	1545[d]	1114[b]	1275[bc]	1326[c]	42.4

[a]AC = ad lib intake of an 80% concentrate diet for 14 weeks; LC = restricted intake of an 80% concentrate diet for 8 weeks followed by 6 weeks ad lib intake of an 80% concentrate diet; F = ad lib intake of forage for 8 weeks followed by 6 weeks ad lib intake of an 80% concentrate diet; F-LC = 6 weeks ad lib intake of forage followed by 2 weeks restricted and 6 weeks ad lib intake of an 80% concentrate diet; transitions from forage to the 80% concentrate diet or from restricted to ad lib intake of the 80% concentrate diet occurred in 1 week.

[b,c,d]Within a row, means lacking a common superscript letter differ ($P < 0.05$).

was % EBH_2Ox 0.27173, and that for % EBASH was % EBH_2Ox 0.06356. To determine energy accretion, 5.52 and 9.4 kcal/g of protein and fat, respectively, were assumed (ARC, 1980).

Statistical Analyses
Data from the animal with urinary calculi were discarded. Data were analyzed by General Linear Models procedures of SAS (1990). Body weight gain and body composition data were first analyzed as a split-plot, with a main plot of dietary treatment, subplot of breed and use of animal within pen to determine significance of the dietary treatment effect. Because effects of neither breed nor the dietary treatmentxbreed interaction were significant, these sources of variation were dropped from the model. Pen was the experimental unit, and differences among means were determined by least significant difference with a protected F-test ($P < 0.05$).

Results and Discussion

Results
Total dry matter intake in weeks 1-6 ranked ($P < 0.05$) AC > F and F-LC > LC (Table 2). Dry matter intake for AC was slightly greater in weeks 7-8 than in weeks 1-6 and 9-14. Intake of concentrate for LC averaged 85% greater in weeks 9-14 than in weeks 1-8. Total dry matter intakes in weeks 7-14 and 9-14 were similar among treatments. However, over the entire 14-week experiment total dry matter intake was greatest ($P < 0.05$) for AC, lowest ($P < 0.05$) for LC and similar between F and F-LC.

As designed, live weight gain in weeks 1-6 was greatest ($P < 0.05$) for AC and similar among LC, F and F-LC (Table 3). However, relative to live weight gain in weeks 1-6, gain in weeks 7-8 was greater for LC and F and similar for F-LC. Thus, in weeks 7-8 live weight gain ranked ($P < 0.05$) AC > LC and F > F-LC. Body weight gain in weeks 9-14 was greater ($P < 0.05$) for LC and F-LC than for AC and F. For weeks 7-14, live weight gain was similar among treatments but numerically lowest for F (e.g., 51 g/day less for F versus F-LC). For the entire experiment, live weight gain was greatest ($P < 0.05$) for AC, greater ($P < 0.05$) for LC versus F and tended ($P = 0.12$) to be greater (i.e., 32 g/day) for F-LC than for F.

The ratio of body weight gain to dry matter intake, or feed conversion ratio, was greatest ($P < 0.05$) among treatments for AC and greater for LC than for F ($P = 0.06$) and F-LC ($P = 0.08$) in weeks 1-6. Conversely, feed conversion ratio was lowest ($P < 0.05$) among treatments for F-LC in weeks 7-8 and greater for LC and F-LC than for AC and F in weeks 9-14. Treatment differences in feed conversion ratio in weeks 7-14 were similar to those in weeks 9-14. The feed conversion ratio for the entire 14-week experiment ranked ($P < 0.05$) AC and LC > F-LC > LC.

Empty body weight after week 8 differed among treatments as did body weight gain in weeks 1-8 (Table 4). In accordance, protein concentration in the empty body was lowest and fat concentration

Table 3. Live weight gain and live weight gain:dry matter intake for wethers in a 14-week growing-finishing period.

		Treatment[a]				
Item	Week	AC	LC	F	F-LC	SE
Live weight gain, g/day	1-6	277[c]	75[b]	53[b]	59[b]	18.0
	7-8	239[d]	124[c]	154[c]	27[b]	21.3
	9-14	191[b]	274[c]	178[b]	289[c]	14.9
	7-14	203	237	172	223	15.8
	1-14	235[d]	167[c]	121[b]	153[bc]	11.7
Live weight gain:dry matter intake (g/kg)	1-6	189[c]	94[b]	47[b]	53[b]	12.5
	7-8	139[c]	139[c]	126[c]	24[b]	14.6
	9-14	122[b]	182[c]	123[b]	182[c]	6.8
	7-14	126[c]	174[d]	124[b]	152[cd]	7.3
	1-14	152[d]	150[d]	95[b]	115[c]	4.9

[a] AC = ad lib intake of an 80% concentrate diet for 14 weeks; LC = restricted intake of an 80% concentrate diet for 8 weeks followed by 6 weeks ad lib intake of an 80% concentrate diet; F = ad lib intake of forage for 8 weeks followed by 6 weeks ad lib intake of an 80% concentrate diet; F-LC = 6 weeks ad lib intake of forage followed by 2 weeks restricted and 6 weeks ad lib intake of an 80% concentrate diet; transitions from forage to the 80% concentrate diet or from restricted to ad lib intake of the 80% concentrate diet occurred in 1 week.

[b,c,d,e] Within a row, means lacking a common superscript letter differ ($P < 0.05$).

and mass were greatest among treatments ($P < 0.05$) for AC. Empty body weight at the end of the experiment was also greatest ($P < 0.05$) for AC, but the magnitude of difference was less than after 8 weeks. The concentration of protein was greater ($P < 0.05$) for F than for AC and LC. Protein mass was greatest among treatments ($P < 0.05$) for AC. The percentage of fat was lowest ($P < 0.05$) among treatments for F, and fat mass was greatest ($P < 0.05$) for AC.

Empty body weight gain in weeks 9-14 was greater ($P < 0.07$) for LC and F-LC than for AC and F (Table 4). Protein accretion was similar among treatments. Fat and energy accretion were lower ($P < 0.05$) for AC than for LC and F-LC and greater ($P < 0.05$) for F-LC than for F. The ratio of energy accretion to estimated (NRC, 1985) metabolizable energy intake during weeks 9-14 was lowest ($P < 0.05$) for AC and greater ($P = 0.07$) for F-LC than for F (194, 345, 286 and 363 kcal/Mcal metabolizable energy intake for AC, LC, F, and F-LC, respectively; SE 21.7).

Discussion

Conditions. The experiment ended at one time and animal age. The period of ad lib intake of concentrate for all animals (6 weeks) was insufficient to allow for LC, F and F-LC wethers to achieve empty body weight similar to that for AC animals. Hence, how treatment effects would differ with a longer period of ad lib concen-

Table 4. Body composition after growing and finishing phases and tissue accretion during finishing for wethers.

	Treatment[a]				
Item	AC	LC	F	F-LC	SE
End of first 8 weeks					
EBW[b], kg	41.2^{d}	31.3^{c}	29.8^{c}	29.1^{c}	1.13
Water, % of EBW	47.5^{c}	53.8^{d}	55.3^{de}	56.4^{e}	0.59
Water, kg	19.5^{d}	16.8^{c}	16.5^{c}	16.3^{c}	0.39
Protein, % of EBW	12.9^{c}	14.6^{d}	15.0^{de}	15.3^{e}	0.16
Protein, kg	5.29^{d}	4.56^{c}	4.47^{c}	4.43^{c}	0.106
Fat, % of EBW	37.4^{e}	30.1^{d}	28.3^{cd}	27.1^{c}	0.69
Fat, kg	15.5^{d}	9.5^{c}	8.5^{c}	8.0^{c}	0.61
Ash, % of EBW	3.02^{c}	3.42^{d}	3.52^{de}	3.58^{e}	0.038
Ash, kg	1.24^{d}	1.07^{c}	1.05^{c}	1.04^{a}	0.025
End of 14-week experiment					
EBW[b], kg	48.4^{d}	41.9^{c}	38.4^{c}	40.1^{c}	1.47
Water, % of EBW	45.6^{c}	47.2^{c}	50.1^{d}	47.9^{cd}	0.62
Water, kg	22.0^{d}	19.7^{c}	19.0^{c}	19.0^{c}	0.51
Protein, % of EBW	12.4^{c}	12.8^{c}	13.6^{d}	13.0^{cd}	0.17
Protein, kg	5.99^{d}	5.35^{c}	5.18^{c}	5.17^{c}	0.139
Fat, % of EBW	39.2^{d}	37.7^{d}	34.2^{c}	37.0^{d}	0.75
Fat, kg	19.0^{d}	15.9^{c}	13.3^{c}	15.0^{c}	0.80
Ash, % of EBW	2.90^{c}	3.00^{c}	3.18^{d}	3.04^{cd}	0.039
Ash, kg	1.40^{d}	1.25^{c}	1.21^{c}	1.21^{c}	0.032
Accretion in weeks 9-14					
EBW, g/day	172^{c}	252^{d}	204^{c}	262^{d}	11.8
Protein, g/day	16.5	19.0	16.7	17.6	2.00
Fat, g/day	84^{c}	151de	115^{cd}	168^{e}	10.1
Energy, Mcal/day	0.88^{c}	1.52^{de}	1.18^{cd}	1.67^{e}	0.092

[a] AC = ad lib intake of an 80% concentrate diet for 14 weeks; LC = restricted intake of an 80% concentrate diet for 8 weeks followed by 6 weeks ad lib intake of an 80% concentrate diet; F = ad lib intake of forage for 8 weeks followed by 6 weeks ad lib intake of an 80% concentrate diet; F-LC = 6 weeks ad lib intake of forage followed by 2 weeks restricted and 6 weeks ad lib intake of an 80% concentrate diet; transitions from forage to the 80% concentrate diet or from restricted to ad lib intake of the 80% concentrate diet occurred in 1 week.

[b] EBW = empty body weight.

[c,d,e] Within a row, means lacking a common superscript letter differ ($P < 0.05$).

trate intake is unknown. Fat concentrations in the empty body appear slightly greater than expected based on ARC (1980), although levels were, as anticipated, greater after 14 versus 8 weeks. Thus, use of these results should perhaps be confined to comparisons of treatments of this experiment. Nonetheless, these results do not seem reflective of an increase in mature weight with growing phase consumption of forage relative to continual ad lib intake of concentrate, as has been suggested for cattle (Owens et al., 1995). Rather, differences in fat accretion appeared primarily responsible for treatment effects on empty body weight gain in weeks 9-14.

Growing. As intended, the level at which feed intake for LC was restricted in weeks 1-6 yielded body weight gain similar to that for F and F-LC. However, live weight gain for F in weeks 7-8 was greater than in weeks 1-6. Responsible factors are unclear, but a similar difference, though of lesser magnitude, was noted for LC. Change in metabolism as the period of restricted nutrient intake proceeded may be partially responsible. Particularly for LC, the basal metabolic rate and, thus, energy used for body weight maintenance may have declined as the period of restricted nutrient absorption advanced (O'Donovan, 1984). Lower body weight gain for F-LC in weeks 7-8 versus 1-6 probably is partially attributable to decreasing gut digesta fill as dietary level of forage was decreased to zero and concentrate intake was gradually increased but only to a restricted level.

Finishing. A consideration for such feeding management systems is the transition from growing to finishing phases, possibly influencing differences in performance among treatments in the present experiment. Obviously, no transition period existed for AC. For LC, the transition period entailed only a step-wise increase in intake of concentrate. The F-LC wethers were subjected to two relatively mild transitions, from ad lib intake of forage in weeks 1-6 to restricted intake of concentrate in weeks 7-8, then to ad lib intake of concentrate in weeks 9-14. Conversely, F wethers incurred only one transition period, but from ad lib intake of forage in weeks 1-8 to ad lib intake of concentrate in weeks 9-14 and after a period of fasting imposed for estimating body composition. Thus, it is conceivable that a longer experiment, starting with younger animals, which would have been more conducive to slower or longer changes between feeding regimes, would have favorably impacted performance of F wethers relative to effects on wethers of other treatments. Although, because no digestive or metabolic disturbances from the transitions were apparent, other factors seem to have contributed to differences among treatments in finishing performance.

The ranking of AC body weight gain of weeks 1-6 > 7-8 > 9-14 reflects grazing of moderate-quality forage before the experiment, resulting in compensatory growth potential, and also wether age (i.e., 9 months) when the experiment commenced. Greater body weight gain in weeks 9-14 for LC and F-LC than for AC can be accounted for by compensatory growth capacity developed from the restricted nutrient intake regimes in weeks 1-8. Based on earlier body weight gain, compensatory growth potential at the start of week 9 for F was similar to that for LC and F-LC, although subsequent body weight gain and feed conversion ratio observed in weeks 9-14 were lower than for LC and F-LC. These results agree with those of Sainz et al. (1995) with beef steers. As noted earlier, a factor possibly contributing to these findings is a difference between growing phase regimes in carryover effects on nutrient use by visceral organs, with concomitant impact on nutrient availability to other tissues. In this regard, Goetsch (1998) suggested that energy use by the gastrointestinal tract and liver is influenced by the quantity of nutrients being absorbed and also by characteristics of digesta in the gut such as the quantity and physical nature. The effects of energy absorption on subsequent visceral organ energy use should have been similar between limited intake of concentrate and ad lib intake of forage in the growing phase. Although, potential exists for dissimilar effects of differences in the quantity and nature of digesta passing through the gut elicited by restricted intake of concentrate versus ad lib intake of forage during the growing phase.

Measures necessary to confirm the aforementioned postulate were not made in the present experiment. Nonetheless, a more rapid decrease with time in energy use by visceral organs relative to absorbed energy for F-LC after forage and(or) limited concentrate consumption than for F after ad lib intake of forage is possible, which encompasses potential influences of changes in the quantity of nutrients absorbed and physical characteristics of digesta. The continued restricted level of energy absorption in weeks 7-8 for F-LC, in concert with changes in the quantity and characteristics of digesta in the gut, might have hastened the rate at which energy use relative to energy absorbed by visceral organs decreased from that with ad lib intake of forage to the level when concentrate was consumed ad lib. The rate of change with F could have been slower since consumption remained ad lib throughout the 14-week period, with marked change occurring in the quantity and characteristics of digesta passing through the gut.

Conclusions

Growing phase ad lib intake of forage may affect subsequent performance with ad lib intake of concentrate differently than restricted intake of concentrate. A period of restricted intake of concentrate following growing phase ad lib intake of forage could offer potential to improve later performance with ad lib intake of concentrate, compared with a shift from ad lib intake of forage to concentrate, and to a level similar to that occurring with change from growing phase restricted intake of concentrate to ad lib intake of concentrate during finishing.

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The Clean Color of U.S. Wool Fiber: Comparison of Scoured and Carded Wools

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Summary

Core samples of wool fibers representing various regions of the U.S. were obtained from Yocom-McColl Testing Laboratories. After scouring, average fiber diameter and clean color were determined. Due to the varying levels of vegetable matter (vm) present in the core residues, the samples were carded to evaluate the effect of removing the excess vm on the color of the wool. The results of clean color of the scoured wool and the carded wool clearly indicated that there were differences between the yellowness of the samples. Carded wools in all cases were less yellow than the scoured

Keywords: wool, clean color, yellowness

Introduction

The color of wool is an important characteristic. It provides for example, a limit to the dyeing potential of that wool. Clean color specification is becoming increasingly more important for wool marketing, especially for both high quality wool and lower types such as pieces and bellies (Australian Wool Corporation, 1987). Greasy wool color is determined not only by the inherent color of the wool, but also by the grease, suint, dirt and vegetable matter the wool contains. These extraneous materials are removed in processing by scouring and carding. Therefore, these impurities do not affect the color of the final product. Thus, before a relevant color measurement can be made, greasy wool must be processed to a state of cleanliness.

Wool processors often find it necessary to remove urine stains, contaminants and other discolored faults from greasy, scoured or carbonized wool in order to improve the quality of their end product. This operation is expensive, tedious and inefficient (Abbott, 1995).

Studies have shown that the greasy color of wool is a poor indicator of the clean color of that wool (Thompson and Whiteley, 1985; Australian Wool Corporation, 1987; Marler, 1992). For example, a wool which appears yellow in the grease form may become "white" after scouring. In addition, the color of commercially processed top has been shown to be correlated with the color of a sample of greasy wool that has been scoured and carded (Marler, 1992).

Soon after wool is shorn it is usually stored in some way. If its clean color is measured, it is usually based on a core sample drawn at this stage. However, it has been shown that color of wool may continue to change during storage (Carnaby and Ranford, 1991). Wool color may also change during subsequent processing due to the accumulated effects of scouring, drying, carding, combing, dyeing and finishing (Cottle and Zhao, 1995).

Processors are paying more attention to the color of wool. A recent study (Cottle and Zhao, 1995) has shown that incubation can bring wool to a more stable color. The color is less likely to change during subsequent storage, scouring or dyeing. Using this information, processors should be able to use this data to better predict the processing performance of raw wool (Cottle and Zhao, 1995). A recent development has been a mill-scale automated color sorting device that is capable of sorting large quantities of undyed fibrous material in a continuous on-line operation and removing colored faults such as stained wool, dark fibers, etc. (Abbott, 1995).

The major wool exporting nations (Australia and New Zealand) place different emphasis on the clean color of wool, with

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New Zealand placing a high emphasis on clean color whereas Australia places a lower emphasis (Baxter, 1995). The reason for this is that New Zealand exports more scoured wool than does Australia and therefore the visual appearance of the wool becomes an important characteristic when supplying wool to a customer (Marler, 1992).

Recent studies under the auspices of IWTO (IWTO, 1999a) have been directed towards developing an IWTO standard test method for measuring color of scoured wools. Draft Test Method-56 (DTM-56) (IWTO, 1999b) Method for the measurement of base and "as is" colour of raw wool allows for the existence of two calibration systems for the measurement of wool color. One systems allows for the use of standard tiles (white and black) while the other allows for the use of WRONZ reference wools with assigned values.

The purpose of this study was to evaluate the color of U.S. wool fiber. Of particular interest was to determine if carding of a scoured wool sample changed the color of that particular wool sample.

Materials and Methods

Fiber Samples

Twenty-six core samples representing various regions of the U.S. were obtained from Yocom-McColl Testing Laboratories Inc. These core samples were processed by Yocom-McColl according to ASTM D584-96 (ASTM, 1998) to obtain clean wool yield, vegetable matter base and average fiber diameter. Fiber samples were given an alkali scour. Breakdown of the samples by state were as follows: 6 samples from Utah, 3 samples from Texas, 4 samples from California, 7 samples from South Dakota, 2 samples from Montana,

Table 1. Average Fiber Diameters

TEST #	ORIGIN	Average Fiber Diameter (microns)	U.S. Clean Yield (%)	Vegetable Matter (%)
71595	UTAH	21.5	44.2	1.5
72013	TEXAS	19.7	56.3	1.7
72014	TEXAS	19.8	50.0	0.8
72062	UTAH	28.9	7.4	1.9
72169	TEXAS	19.8	47.5	1.3
72312	UTAH	22.7	49.8	1.0
72500	CALIFORNIA	28.9	63.6	1.1
72508	CALIFORNIA	23.6	59.8	1.7
72511	MONTANA-1	20.9	50.1	0.8
72530	CALIFORNIA	20.6	54.2	1.3
72534	OHIO	28.9	58.1	1.2
72555	KANSAS	21.2	52.1	1.5
72556	KANSAS	23.3	56.5	1.2
72564	SOUTH DAKOTA	22.0	54.4	2.2
72565	SOUTH DAKOTA	25.6	57.9	2.8
72566	SOUTH DAKOTA	26.9	59.7	2.0
72567	SOUTH DAKOTA	23.5	54.9	2.7
72598	UTAH	24.7	51.7	1.6
72603	UTAH	25.6	54.2	2.9
72604	NEVADA	22.8	48.7	2.1
72605	SOUTH DAKOTA	23.5	51.5	1.3
72610	CALIFORNIA	26.3	59.7	2.3
72616	UTAH	27.3	54.0	2.0
72617	MONTANA-2	32.8	72.0	0.2
72641	SOUTH DAKOTA	21.9	56.7	0.9
72642	SOUTH DAKOTA	21.1	53.1	1.8

1 sample from Ohio, 2 samples from Kansas and 1 sample from Nevada. The scoured core residue was then measured for color. These residues had varying levels of vegetable matter (vm) present so it was decided that the samples should be carded to evaluate the effect of removing excess vm on the color of the wool sample.

Determination of Fiber Diameter
Fiber diameter of the scoured core residue was measured using the Sirolan-Laserscan. (IWTO-12, 1993). A subsample of the core residue was minicored to obtain 2mm long fiber snippets which were subsequently utilized to determine average fiber diameter, standard deviation and coefficient of variation of the sample.

Determination of Yellowness Indices
Yellowness indices were determined using a Spectrogard Color Control System (Pacific Scientific). ASTM E313-96 (ASTM, 1998) was utilized to calculate yellowness indices (YIE). In addition, the Y/Y-Z value of yellowness was also determined. The Y value indicates the lightness of the wool sample (lightness generally ranges between 50-70) with the higher values denoting lighter wools. Y-Z denotes the yellowness of the sample and generally ranges from -2 to 12. The higher the value, the greater the yellowness (Cottle et al., 1992). Eight measurements per sample were taken for both the scoured and subsequently carded wool samples.

Statistical Analysis
Statistical analyses were conducted using the SAS system (SAS Institute, 1995). T-tests were used to determine differences in color between paired scoured and carded wool samples.

Results and Discussion

Average fiber diameters, yield and vm content for the wool samples are shown

Table 2. Yellowness Indices of Scoured and Carded Wool - California, Kansas, Ohio, Texas and Utah

		Scoured		Carded	
TEST #	ORIGIN	YIE[1]	Y[2]/Y-Z[3]	YIE[1]	Y[2]/Y-Z[3]
71595	UTAH	23.1± 1.3	62.4/5.8	20.1± 0.5***	63.3/3.6
72013	TEXAS	26.1± 3.3	61.3/7.8	24.0± 0.5	66.8/6.9
72014	TEXAS	27.6± 1.1	65.0/9.4	26.3 ± 0.5	67.3/8.8
72062	UTAH	23.3± 2.0	54.4/5.2	21.3± 0.4*	64.0/4.5
72169	TEXAS	25.6± 1.4	63.5/7.7	24.6 ± 0.2	68.1/7.5
72312	UTAH	24.0± 0.9	65.1/6.7	21.1 ± 0.3***	66.5/4.6
72500	CALIFORNIA	28.8± 1.7	61.8/9.9	24.8 ± 0.8***	65.6/6.8
72508	CALIFORNIA	22.5± 1.1	64.7/5.5	20.0 ± 0.3***	68.5/3.8
72530	CALIFORNIA	29.3± 2.9	58.3/9.6	23.0 ± 0.6***	66.8/6.1
72534	OHIO	32.0± 3.1	51.9/10.2	28.0 ± 0.3**	63.7/9.5
72555	KANSAS	28.4± 1.9	59.5/9.2	26.8 ± 0.7*	67.1/9.1
72556	KANSAS	29.7± 1.9	65.4/9.5	26.1 ± 0.4***	66.3/8.5
72598	UTAH	26.8± 2.0	59.6/8.1	23.7 ± 0.9**	65.8/6.5
72603	UTAH	25.5± 1.3	60.2/7.2	22.5 ± 1.1***	70.2/6.0
72604	NEVADA	26.1± 1.9	61.3/7.8	21.0 ± 0.6***	67.7/4.6
72610	CALIFORNIA	29.7± 2.5	62.1/10.6	26.0 ± 0.3**	65.1/8.3
72616	UTAH	27.5± 2.2	60.6/8.7	22.3 ± 0.7***	65.3/5.4

***Carded wool significantly less yellow than scoured wool at $p < 0.001$
**Carded wool significantly less yellow than scoured wool at $p < 0.01$
* Carded wool significantly less yellow than scoured wool at $p < 0.05$

[1]YIE - a measure of yellowness according to ASTM E313
[2]Y is a measure of lightness
[3]Y-Z is a measure of yellowness

in Table 1. There is a wide range of fiber diameters with samples ranging from 19.7 - 32.8 microns. Fine wools were obtained from Texas (19.7-19.8 microns), fine to medium wools from Utah (21.5-27.3 microns), South Dakota (21.1-26.9 microns), Kansas (21.2-23.3 microns), California (20.6-28.9 microns) and medium wools from Ohio (28.9 microns), and Nevada (22.8 microns). In the case of the two wool samples from Montana, they were treated as separate samples in further color evaluations because they were so different in terms of fiber diameter (a fine wool (20.9 microns) and a coarse wool (32.8 microns). Clean yields ranged from a high of 72% to a low of 44.2%, while vm ranged from a high of 2.9% to a low of 0.2%.

Yellowness indices of 17 pairs of scoured and subsequently carded wools for California, Kansas, Nevada, Ohio, Texas and Utah are shown in Table 2. The results clearly indicated that carding improved (decreased) the yellowness of the samples. A lower value for YIE and Y-Z indicates a sample that is less yellow or a sample that is more "white". In all cases, except for the three wools from Texas, the yellowness indices of the carded wools were significantly less yellow than those of the scoured wools. While not being significantly different, the yellowness of the Texas wools after carding were arithmetically less than the scoured wools. These results were as expected as carding is a further cleaning process and thus would be expected to remove further dark colored extraneous material which can impact the overall clean color of wool. In fact there is an accumulative effect with scouring and carding which can be taken even further with subsequent combing, dyeing and finishing in changing the color of wool.

The yellowness of the wools when scoured ranged from a high of 32.0 to a low of 22.5 (YIE) and a high of 10.6 to a low of 5.2 (Y-Z), while with the carded wools the yellowness ranged from a high of 28.0 to a low of 20.1 (YIE) and a high of 9.5 to a low of 3.6 (Y-Z). Thus there is a wide variation when looking at individual wool samples. When evaluating the lightness of the wool samples (Y value), for scoured wools the values ranged from a low of 51.9 to a high of 65.4 while for the carded wools the values ranged from a low of 63.3 to a high of 70.2. In terms of lightness these wools compare favorably with Australian wools which generally have Y values which range from 58-66 (Cottle et al., 1992). However, in terms of yellowness, it would appear that even after carding the wools continue to be quite yellow. Australian wools by comparison generally have Y-Z values ranging from 1-4 (Cottle et al., 1992). Only two of the wools from this group had Y-Z values of less than 4 even after carding. Some of the differences in yellowness compared to Australian wools may possibly be explained by the fact that Australian wools are typically given a neutral detergent scour which generally results in a whiter (less yellow) fiber.

Yellowness indices for 9 pairs of scoured and subsequently carded wools for

Table 3. Yellowness Indices of Scoured and Carded Wool - Montana and South Dakota.

		Scoured		Carded	
TEST #	ORIGIN	YIE[1]	Y[2]/Y-Z[3]	YIE[1]	Y[2]/Y-Z[3]
72511	MONTANA-1	24.1± 0.9	64.2/6.7	21.3 ± 0.8***	70.9/5.0
72564	SOUTH DAKOTA	25.2 ± 1.1	63.3/7.4	21.2 ± 0.2***	68.7/4.8
72565	SOUTH DAKOTA	21.9 ± 1.3	65.9/7.2	20.3 ± 2.4	67.2/4.0
72566	SOUTH DAKOTA	23.5 ± 2.0	65.4/6.4	19.4 ± 1.3***	67.5/3.3
72567	SOUTH DAKOTA	26.8 ± 2.2	59.5/8.1	24.1 ± 1.1**	66.0/6.9
72605	SOUTH DAKOTA	27.5 ± 1.4	62.2/9.0	23.8 ± 0.7***	69.4/6.9
72617	MONTANA-2	34.3 ± 1.6	59.0/13.2	32.2 ± 1.0*	61.5/12.3
72641	SOUTH DAKOTA	25.6 ± 2.7	65.6/8.0	20.0 ± 1.3***	71.5/4.0
72642	SOUTH DAKOTA	23.3 ± 1.2	66.3/6.3	20.9 ± 1.2***	69.8/4.6

***Carded wool significantly less yellow than scoured wool at $p < 0.001$
**Carded wool significantly less yellow than scoured wool at $p < 0.01$
* Carded wool significantly less yellow than scoured wool at $p < 0.05$

[1] YIE - a measure of yellowness according to ASTM E313
[2] Y is a measure of lightness
[3] Y-Z is a measure of yellowness

Montana and South Dakota are shown in Table 3. Carding again significantly improved the yellowness of the samples in all but one case. One wool from South Dakota did not significantly change. However, while not being significantly different, the yellowness of this wool was still less than the scoured wool.

The yellowness of these wools when scoured ranged from a high of 34.3 to a low of 21.9 (YIE) and a high of 13.2 to a low of 6.3 (Y-Z), while with the carded wools the yellowness ranged from a high of 32.2 to a low of 19.4 (YIE) and a high of 12.3 to a low of 3.3 (Y-Z). Thus there is a wide variation when looking at individual wool samples. When evaluating the lightness of the wool samples (Y value), for scoured wools the values ranged from a low of 59.0 to a high of 66.3 while for the carded wools the values ranged from a low of 61.5 to a high of 71.5.

When comparing the lightness and yellowness of these wools to Australian wools it is again evident that in terms of lightness these wools compare favorably with Australian wools. However, in terms of yellowness, even after carding the wools continue to be quite yellow. Only 3 of the wools have Y-Z values of 4 or less. Some of the difference could again possibly be explained by the fact that these wools were given an alkali scour which generally causes fibers to be more yellow compared to those given a neutral detergent scour (typical for Australian wools). Additionally, commercial scouring operations typically dry wool at temperatures of between 80-120°C for 2½ - 5 minutes depending on the type of dryer. Both IWTO and ASTM standards for the laboratory scouring of wool call for drying the wool samples at a temperature of 105±2°C to constant mass. Drying at elevated temperatures has the potential for discoloring wool (causing additional yellowness). For example IWTO Draft Test Method 56 (1999b) cautions against prolonged drying at 105°C as it can yellow some wools and thus should be avoided.

Conclusion

It is evident from these results that in many instances there may be problems associated with the color of U.S. wools. There are significant differences among and within regions. There also does not appear to be any correlation between fiber diameter and color. Subsequent carding or scoured wool in most cases significantly improved the color of the samples.

As a comparison, Australian wools generally have yellowness indices (Y-Z) of 1-4 (Cottle et al., 1992). Based on our analysis there were individual wool clips that would compare favorably with Australian wools. However, as a general rule, U.S. wools seem to be yellower. In many cases U.S. clips may be brought up to Australian standards through improved preparation at shearing time and by utilizing neutral detergent scouring processes. Thus it would appear as far as potential marketing, both domestic and internationally, the color of U.S. wools is something that needs to be addressed.

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Research Note

Sheep Grazing to Control Wheat Stem Sawfly, a Preliminary Study[1]

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Wheat stem sawfly (Cephus cinctus Norton, WSS) is the most damaging insect or disease pest to Montana's $1 billion/year grain industry with an economic impact estimated in excess of $30 million/year (Blodgett et al. 1996). Wheat stem sawfly is distributed throughout the Northern Great Plains from the Dakotas and Nebraska into Idaho and south into Wyoming. Originally a pest of spring wheat (Triticum aestivum), the adult emergence period has gradually shifted earlier, making WSS a significant winter wheat pest (Morrill & Kushnak 1996). Adults emerge in early summer and females lay single eggs within an elongating wheat stem. Eggs hatch and larvae feed on parenchyma tissue within the stem. As wheat matures, the larva completes its feeding, and travels to the base of the stem where it cuts and plugs the stem behind it forming a stub in which it spins a cocoon to form its over-wintering cell. Larval cutting and plugging weakens the wheat stem causing lodging and rendering the grain head unharvestable.

Increase in WSS infestations over the past 5 years in both winter and spring wheat (Anonymous, 1997) has increased the urgency to develop economical and effective WSS management strategies. Pesticide applications target the adult, the only life stage that occurs outside of the plant, and provide limited control because adults are non-feeding and emerge over a 4 to 6 week period (Johnson and Morrill, unpublished). Techniques such as tillage (Goosey, 1999) or burning provide some reduction but cause other problems including soil erosion and negative impacts on water and air quality. In addition, Dormaar et al. (1979) and Biederbeck et al. (1980) reported an economic loss with long-term stubble burning. Although WSS biological control agents have been identified (Nelson and Farstad 1953), they do not offer consistent population reductions. Resistant strains of wheat have also been developed (McNeal et al. 1971), however, yield reductions of 10% occur over that of susceptible wheat varieties.

Our objective was to evaluate the influence of sheep grazing on overwintering WSS larva numbers in a WSS infested wheat stubble field. The project goal is to economically control WSS possibly by disrupting the overwintering environment of the larva, exposing them to changes in temperature and moisture resulting in lower WSS survival or via consumption of the stems containing the WSS larva.

A randomized complete block design with 4 blocks and 4-112m² plots/block was used in this study. Treatments were 1) control (no grazing), 2) fall grazing (October 15, 1998), 3) spring grazing (May 4, 1999), and 4) fall and spring grazing. Four or five mature Targhee ewes were randomly assigned to plots designated for grazing. Ewes were confined to plots for 24 hours with net electric fence and had ad libitum access to water. Fall and spring stocking rates were 400 or 500 sheep d/ha based on Thomas et al. (1990) recommendation of 420 sheep d/ha on Montana wheat stubble. Stocking rate in the plots grazed in both the fall and spring were twice the rate of the fall only and spring only grazed plots.

The response variable was number of live WSS/ha in the spring immediately prior to the expected WSS adult emergence. Wheat stem sawfly populations were determined on October 9, 1998 (6 days

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before fall grazing) and May 13, 1999 (9 days after spring grazing). Numbers of WSS were determined by collecting all stubble material (including roots and stems) in a 0.6 m length along a single row of wheat stubble in each plot on each date. Samples were returned to the laboratory, where wheat stems were counted and individual stems dissected to determine if they contained a live WSS larva. Data were analyzed as a randomized complete block design using the general linear model procedure of SAS (1985). Data collected on October 9 was used as a covariable to evaluate the response to treatments on May 13.

Compared to a non-grazed control, grazing wheat stubble with sheep in the fall and fall/spring reduced WSS larva numbers on May 13 by 60 ($P = .11$) and 87% ($P = .05$), respectively (Figure 1). Spring grazing and control plots did not differ ($P = .26$) in WSS larva numbers, although spring grazing resulted in a 46% reduction in larva numbers on May 13 compared to the control.

This method of controlling WSS infestations indicates a positive response compared to other methods currently practiced. Fall and spring tillage was found to be ineffective at reducing overwintering WSS infestations (Goosey 1999). Although the incorporation of swathing into the grain harvesting process reduced WSS populations by 23 – 33%, it did not provide sufficient WSS reductions to be a recommended practice for WSS management (Goosey 1999).

Other methods currently used for WSS management including pesticides, burning, and resistant wheat varieties are either costly, ineffective, or result in lower wheat yields (Bowman et al., 1996). Thus they are not sufficiently effective to be recommended as sole use solutions for WSS management. This study demonstrates the potential of using grazing sheep to control wheat stem sawfly, a serious problem in wheat production. In addition, to potentially being a cost-effective method, the integration of sheep into small grain production may offer other benefits to small grain production such as weed control and improved soil nutrient cycling.

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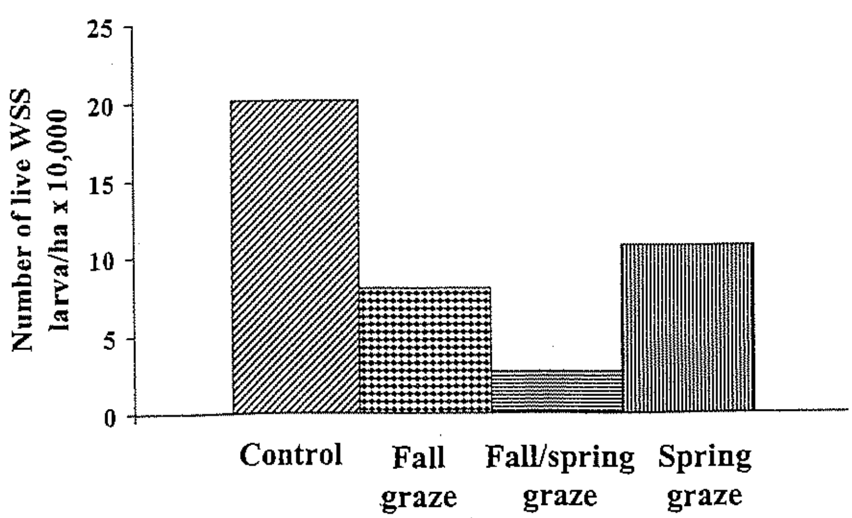
Figure 1. Number (x 10,000) of live wheat stem sawfly larvae per hectare on May 13. Standard error of least squares means = 5.6. P value for mean comparison of control vs fall, fall/spring, and spring grazing are 0.11, 0.05. and 0.26, respectively.



Sheep and Goat Research Journal

News Briefs

Sheep Center and NLPA sign agreement

National Sheep Industry Improvement Center Chairman Pierce Miller and National Livestock Producers Association Chairman Sam Philips signed a long-awaited grant agreement on Thursday, November 18, in a joint meeting of their respective groups in Denver.

"Earlier this year we identified two major priorities for the year — the intermediary grant agreement and legislation that would correct some of our most pressing problems," said Miller at the signing. "With the Sheep Center corrective language as part of the Ag Appropriations bill signed into law last month, and the signing of the grant agreement today, we have met those goals.

"Getting this program into the industry has always been our top priority and this grant agreement provides that mechanism."

The National Sheep Industry Improvement Center (Sheep Center) was established as part of the 1996 Farm Bill to aid the nation's ailing sheep and goat industries. The Sheep Center was designed as an innovative new revolving fund to provide capital to the sheep and goat industries for marketing and infrastructure developments. Since February 1997, the Board of Directors, which is the governing body appointed by the Secretary of Agriculture, has pursued a number of actions to get the unique program working.

"The use of a single intermediary, the National Livestock Producers Association, is a giant step toward realizing our goal of getting the Sheep Center monies working in the sheep and goat industries," said Miller.

It was determined that a qualified intermediary must have: 1) an interest in the Sheep Center's goals, mandates and the relatively small size of the grant; 2) expertise with livestock production, processing or marketing related lending; 3) nationwide capability in urban and rural areas; and 4) the ability to process and service loans from all segments of the sheep and goat industries, from production through the packer/processor/retail level.

Finding a qualified intermediary has been a lengthy process, beginning in February 1999. Of those that initially seemed qualified, the National Livestock Producers Association (NLPA) was the only organization that met the requisite qualifications.

NLPA is headquartered in Colorado Springs, Colo. It was founded in 1921 and has nationwide lending capabilities through its subsidiary organizations. It can process and service loans from all segments of the sheep and goat industries, either directly or through contract services.

The grant agreement specifies the parameters for the use of the funds and the reporting and accounting requirements to the Sheep Center board. The grant agreement further requires formation of an oversight "Sheep and Goat Committee" within the intermediary that will administer the grant. It details how the oversight committee will be formed and requires that sheep and goat expertise be represented on the committee. NLPA has agreed to all of these terms.

Applications for entities interested in applying for loans will be available January 1, 2000. They may be requested from either the National Livestock Producers Association at (800) 237-7193 or the National Sheep Industry Improvement Center at (303) 236-2858. More information will also be available on NLPA's website at www.nlpa.org.

Incorporators sign articles of incorporation creating the National Institute for Animal Agriculture

Five individuals made history on September 15, 1999 by signing articles of incorporation creating the National Institute for Animal Agriculture. The new organization will be the successor to the Livestock Conservation Institute and will begin operations January 1, 2000.

Serving as Incorporators of the new organization were Thomas W. Wenstrand, chairman of the LCI board, Richard D. Hull, vice chairman of the LCI board, Richard E. Breitmeyer, chairman of the LCI Vision 2000! Task Force, Neil V. Anderson, LCI treasurer and James E. Stocker, LCI board member.

According to the legal language of the Articles of Incorporation, the purpose of the new organization will include:

- to engage in and promote educational programs and materials which purposes are to advance animal agriculture,
- to provide a forum among organizations, allied industries, researchers and individuals for the purposes of building consensus, and advancing solutions,
- to correlate, coordinate and disseminate data and information relative to animal agriculture, and
- to provide continuing education and communication linkages for animal agriculture professionals.

A business plan, currently being developed, will articulate the organization's purposes and areas of emphasis in greater detail.

LCI executive director Glenn Slack says that among the various purposes of the new organization, he is pleased that NIAA will fill a void by providing continuing education opportunities for professionals involved in animal agriculture.

"Many professionals in the industry obtain a college degree and are having to rely on that training years later," observes Slack. " The information age will have our society, animal agriculture no exception, evolving very rapidly and continuing education will become increasingly important to remain a participant."

Slack explains that NIAA will provide personal growth conferences and workshops that will target the needs of those involved in animal agriculture, as well as facilitate an annual international study tour to educate a broader constituency on the global business culture.

LCI has predominately focused on the pork, beef and dairy cattle, and sheep industries. NIAA will continue to focus on these species — enhancing representation in some cases — and explore a new interest area with the equine, avian and aquaculture industries.

In addition to the signing of the articles and bylaws, the Incorporators appointed an initial 15 member board of directors to serve until the first meeting of the organization in April 2000. The officers of the organization will consist of a chairperson of the board, a vice chairperson, a president, a secretary and a treasurer.

The Bylaws call for two types of membership: full members and affiliate members. Affiliate members are those members who have an interest in supporting the purposes of the organization, but they do not have voting rights.

During the organization's first meeting in 2000, a new board of directors will be elected by the membership on staggered terms. The meeting is scheduled for April 10-14, 2000 in Corpus Christi, Texas.

Slack said the net result of these changes will be a more modern, more efficient organization to serve animal agriculture in the next quarter century and beyond.

Sheep & Goat Research Journal

Guidelines for Authors

Objective

The aim of the Sheep & Goat Research Journal is to publish timely sheep and goat research findings that can be used by scientists, educators, extension agents, and producers alike. Specifically, the Journal aims to encourage producer use of research that has practical application

Editorial Policy

The Sheep & Goat Research Journal publishes articles of research relating to all aspects of sheep and goat production including marketing. Articles should relate and contribute to the advancement of the American sheep and goat industries and / or their products. All research articles must represent unpublished original research and conclusions reached must be supported by research results. Articles that promote commercial products or services will not be approved for publication. Articles that promote practical applied research are encouraged. The submission of review articles is accepted but will require the same review process as other submitted articles. At least one author of each submitted article must subscribe to the Journal. All manuscripts and correspondence should be addressed to Sheep & Goat Research Journal, P.O. Box 51267, Bowling Green, KY 42102-5567. Inquiries may be sent via electronic mail at sheep2goat@aol.com.

Review Process

Manuscripts will be subject to critical review by an editorial board or others designated by the editor. Authors will be notified by mail of acceptance or rejection of papers. Manuscripts needing revision will be returned to authors and should be revised and returned by the deadline indicated. Papers not suitable for publication will be returned to the authors with a statement of reason for rejection. Consult the Sheep & Goat Research Journal Editorial Policy and Procedures for details of the technical requirements for manuscripts submitted to the Journal.

Manuscript Submission

Manuscripts should be mailed to the Sheep & Goat Research Journal, P.O. Box 51267, Bowling Green, KY 42102-5567. Five copies of each manuscript must be submitted. Each manuscript must be accompanied by a cover letter from the main corresponding author. The cover letter must include the mailing address, telephone and fax numbers, and e-mail address of the corresponding author. As a style reference, authors may refer to the Publication Manual of the American Physiological Association. Every effort is made to publish papers promptly. Normally, a paper is published approximately six months after it is received from the authors.

Format

Manuscripts must be typed and double-spaced. 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. Submission of excessive tabular data is discouraged; tables should be limited to that data that is considered essential to the research findings. Tables must be typed, double-spaced, and placed 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.

The following format should be used when submitting research manuscripts:

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**

When 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." Please provide "interpretive summaries" for use by the sheep and goat industries in other media.

Proofing

Primary authors will receive galley proofs of articles for review. 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 asked to complete a reprint order form.

Charge

The publication charge for the Sheep & Goat Research Journal is $60.00 per page; position announcements are $30.00 per quarter-page or less. Authors will be billed after publication.