RESEARCH REPORTS

CPR - 5257
September 1996

Sheep and Goat, Wool and Mohair, 1996

Texas Agricultural Experiment Station
Edward A. Hiler, Director
The Texas A&M University System
College Station, Texas

Foreword

The 1996 Sheep and Goat/Wool and Mohair Consolidated Progress Report has been prepared by Texas Agricultural Experiment Station and Extension Service scientists to communicate current research activities and results to those involved in all phases of the sheep and goat industry. Our objective is to get results to the industry as rapidly as possible. More detailed information on any subject in this report may be obtained by contacting the responsible scientist(s) directly.

Sheep and goat research in Texas is a consolidated effort involving the scientists working at College Station, San Angelo, Sonora, and other research sites. These scientists maintain close communication with scientists at other Texas universities and in other states, including those with the USDA. Additionally, linkages are established with research organizations in other countries where sheep and goat research is being conducted. Through this network, we maintain a prompt awareness of new developments and emerging technology that may be useful in Texas. The research program maintains relationships with sheep and goat commodity groups and other private organizations involved with animal health care products; feed supplements; ration additives; growth promotants; wool, mohair, and lamb processing and marketing; and other products and concepts that may be useful in sheep and goat production. A new Sheep and Goat Center currently under construction at Texas A&M University College Station, will greatly enhance our ability to address important issues for the sheep and goat industries.

Texas leads the nation in both sheep and goats, and needs to maintain a viable sheep and goat industry in order to efficiently utilize and manage a sustainable range resource. These animals also provide an important economic diversity for land managers and base support to the rural communities in West Texas.

The loss of the USDA wool and mohair incentive removed a stabilizing factor for the industry, and has resulted in a substantial decline in numbers. However, there are limited alternative uses for much of the lands where sheep and Angora goats are raised. Cattle numbers can be increased only slightly but can not replace the income and range management options provided by sheep and goats. The relative large number of manuscripts related to meat goats in this report is evidence that there is considerable interest in further developing this phase of the industry.

The primary objective of the TAES research program is to provide new technology to maintain a productive and profitable Texas sheep and goat industry. We are pleased to provide this overview of research and related studies conducted by Research and Extension staff. Please contact any of us if we can be of assistance.

Carl Menzies, Resident Director
Texas A&M University Agricultural Research
and Extension Center at San Angelo

Bryan Johnson, Head
Animal Science Department
Texas A&M University, College Station

Authors

Baldwin, Jr., B.C., Research Associate,
Texas Agricultural Experiment Station, San Angelo

Bales, K.W., Research Associate,
Texas Agricultural Experiment Station, San Angelo

Brodie, S.J., Assistant Research Professor,
University of Washington, Seattle, WA

Brooks, T.D., Research Associate,
Texas Agricultural Experiment Station, Sonora

Byrns, S., Communications Specialist,
Texas Agricultural Extension Service, San Angelo

Calhoun, M.C., Professor,
Texas Agricultural Experiment Station, San Angelo

de la Concha-Bermejillo, A., Assistant Professor,
Texas Agricultural Experiment Station, San Angelo

DeMartini, J.C., Professor,
Colorado State University, Fort Collins, CO

Dockerty, T.R., Director of Research Information,
National Cattlemen's Beef Association, Chicago, IL

Engdahl, B.S., Research Assistant,
Texas Agricultural Experiment Station, San Angelo

Engdahl, G.R., Professor,
Angelo State University, San Angelo

Forster, Jr., L.A., Asst. Dir. Research and Education
National Cottonseed Products Assoc., Memphis, TN

Fritz, K.D., former Graduate Student,
Texas A&M University, College Station

Goodson, K.J., Graduate Student,
Texas A&M University, College Station

Gootwine, E., Research Scientist,
Ag Research Organization, Israel

Griffin, D.B., Assistant Professor,
Texas A&M University, College

Hale, D.S., Associate Professor,
Texas A&M University, College Station

Holland, E.R., County Agent - Agriculture,
Texas Agricultural Extension Service, Kerr County

Huston, J.E., Professor,
Texas Agricultural Experiment Station, San Angelo

Johnson, H.K., Exec. Dir.Value Based Retail Market,
National Cattlemen's Beef Association, Chicago, IL

Juste, R.A., Investigator,
Servicio de Investigació y Mejora Agraria, Derio,
Spain

Kuhlmann, S.W., Research Associate,
Texas Agricultural Experiment Station, San Angelo

Kwang, J., Research Microbiologist,
U.S. Meat Animal Research Center, Clay Center, NE

Lewis, S.J., Student Worker,
Texas Agricultural Experiment Station, San Angelo

Lorenzen, C.L., Graduate Student,
Texas A&M University, College Station

Lupton, C.J., Professor,
Texas Agricultural Experiment Station, San Angelo

Machen, R.V., Assistant Professor,
Texas Agricultural Extension Service, Uvalde

Magnus-Corral, S., Research Volunteer,
Texas Agricultural Experiment Station, San Angelo

Martin, A.M., former Graduate Student,
Texas A&M University, College Station

Menzies, M.D., former Graduate Student,
Texas A&M University, College Station

Miller, R.K., Associate Professor,
Texas A&M University, College Station

Montgomery, G., Research Scientist,
Agresearch, New Zealand

Oman, J.S., Program Assistant for The Ag Program,
Texas A&M University, College Station

Pfeiffer, F.A., Research Associate,
Texas Agricultural Experiment Station, San Angelo

Ramsey, W.S., Assistant Professor,
Texas A&M University, College Station

Rhee K.S., Professor,
Department of Animal Science, College Station

Salisbury, M., Graduate Assistant,
Angelo State University, San Angelo

Savell, J.W., Professor,
Texas A&M University, College Station

Skaggs, C.L., Assistant Professor,
Texas A&M University, College Station

Taylor, Jr., C.A., Professor and Superintendent,
Texas Agricultural Experiment Station, Sonora

Taylor, T.A., Sheep and Goat Center Manager,
Texas A&M University, College Station

Thigpen, Jr., L.W., County Agent - Agriculture,
Texas Agricultural Extension Service, Bandera County

Thompson, P.V., Senior Research Associate,
Texas Agricultural Experiment Station, San Angelo

Waldron, D.F., Assistant Professor,
Texas Agricultural Experiment Station, San Angelo

Walter, J.P., Associate Professor,
Texas A&M University, College Station

Wheaton, J.E., Professor,
University of Minnesota, St. Paul

White, K.G., County Agent - Agriculture,
Texas Agricultural Extension Service, Uvalde County

Williams, J.D., Associate Professor,
Texas A&M University, College Station

Willingham, T.D., Research Associate,
Texas Agricultural Experiment Station, San Angelo

Ziprin, Y.A., Technician,
Department of Animal Science, College Station

Contents

Explanation of (P > .05)

Dan Waldron

Much of the research in this report has an aim of making a comparison between different animals or animal products (wool and mohair). Some experiments have the objective of comparing different breeds of animals, while some experiments are comparing the same type of animals that are given different treatments. These treatments are often different feed and(or) management. A brief explanation of the implications of the statistical meaning of (P < .05) is given here in order to make this progress report more useful to all readers.

Significant differences when comparing groups or treatments

Several reports will show the differences among groups and include statements such as `Group A was heavier (P < .05) than Group B' or `Group A was significantly (P < .05) heavier than Group B' or `Group A was not significantly (P > .05) heavier than Group B.' The word significantly, as used in this context, refers to the confidence the researcher has in the observed result. The (P < .05) is read: probability less than .05. This indicates that there is less than a 5% probability that the advantage of A over B was not due to the treatment, A vs B, but was due to chance. If P > .05 probability greater than .05, is used, it indicates that there is greater than a 5% chance that the difference between the averages of the two groups is due to chance. In general, a researcher will consider differences between two groups to be not significant if the probability of the difference being due to chance, rather than the treatment used in the experiment, is greater than 10%. The p-value in P < .05, is a measure of the confidence that a researcher has in the result of the experiment. Smaller values indicate a greater confidence.

As a simplified example, assume that a research project was conducted to measure weight gain of two groups of lambs, A and B, in a 30-d period. The average gain of Group A was 14 lb and the average gain of Group B was 12 lb. This would be a significant difference if each of the lambs in Group A gained 14 lb and each of the lambs in Group B gained 12 lb. However, if the Group A lambs' gains ranged from 8 to 20 lb and the Group B lambs ranged from 6 to 18 lb, the difference between the treatments (14 - 12 = 2) might not be significant. Therefore, the variation within a group is considered when determining how much confidence one should have in a difference between groups. A research report may include a statement such as `The higher average gain of Group A over Group B was not statistically significant.' This could be restated as `Because the variation of gain within each group of lambs was so high, the fact that the average for Group A was greater than the average for Group B may not be repeated if this experiment were conducted again.'

A group of animals of similar breeding will not all gain the same or have fleeces with the same fiber diameter. This variation among animals has to be taken into account when describing differences seen in research trials. Using the concept of statistical significance is the accepted way to take into account the biological variation. The variation may be due to genetics (unless animals are identical litter mates or clones they will have some differences in their genetic makeup), health, nutrition, behavior, environment, or a combination of these factors.

Reproductive Performance, Serum Antibody Titers, and FSH Levels of Rambouillet Ewes Passively Immunized Against Inhibin

T.D. Willingham, D.F. Waldron, and J.E. Wheaton

ABSTRACT

Two experiments were conducted to evaluate the effect of passive immunization with an inhibin antibody on reproduction in Rambouillet ewes. Ninety-six ewes were used in each experiment. Passive immunization with increased antibody titers ($P < .01$) in Rambouillet ewes in two years' experiments. FSH levels were higher ($P < .01$) in treated ewes 24 h after immunization. Immunization increased ovulation rate ($P < .01$) for all ewes in Experiment 1 and for the 3-yr-old ewes in Experiment 2. Days to estrus, fertility, lambs per ewe exposed and prolificacy were not affected by immunization. Timing of immunization in relation to CIDR removal had no effect on antibody titer, FSH levels, fertility, or lamb production of treated animals. However, immunization 24 h prior to CIDR removal did increase ovulation rate and decrease days to estrus when compared with 0 or 48 h. Ovulation rate response to immunization was found to be positively related to body weight at breeding.

Introduction

Improvement of reproductive efficiency has long been a major focus of sheep research because of its importance (Shelton, 1980) to overall efficiency of meat production. Methods evaluated for improving reproductive efficiency have included genetic selection and edocrine manipulation. Genetic methods have included within breed selection, or crossbreeding to prolific breeds; while endocrine manipulation has evaluated the use of exogenous hormones, immunization against endogenous steroids or gonadal proteins. The use of immunization has the potential to elicit an immediate response which can be long term (active immunization) or short term (passive immunization). Research evaluating active immunization against androstenedione has shown that reproductive levels can be increased (Willingham et al., 1991) but these increases are generally considered excessive for extensive range production of sheep. Recent developments in the isolation of inhibin, a naturally occuring glycoprotein in the ewe (Burger, 1988; Ying, 1988), development of antisera (Meyer et al., 1991) and positive early trials (Kusina et al., 1995) have increased interest in the potential use of immunization against inhibin for improving reproduction. It is the purpose of these trials to evaluate passive immunization against inhibin and its effects on antibody titer levels, serum FSH concentrations, and reproductive performance in Rambouillet ewes maintained on range.

Materials and Methods

In the fall of 1994 ninety-six, mature Rambouillet ewes (121.4 $\pm$ 1.2 lb) were randomly assigned to four treatments. Ewes were treated intravaginally with a controlled internal drug release device (CIDR) containing progestin for 13 d to synchronize estrus. Treated ewes were passively immunized with an intramuscular injection of an inhibin-antibody at either 48 (-48 h), 24 (-24 h) or 0 h before CIDR removal. A control group was not immunized. Dosage was 4,536 RP-2U/lb for a mean body weight of 121.5 lb. Control and treated ewes were further randomly assigned to three breeding groups (1, 2, 3) within each of the four treatment groups. Each breeding group had 32 ewes with eight from the control group and eight from each of the treatment groups. Breeding group 1 (BG1) ewes were placed with three fertile males at CIDR removal. BG2 and BG3 ewes were placed with four vasectomized rams. All rams were fitted with a marking harness to aid in detection of estrus. Ewes were checked daily for estrus throughout the first estrous cycle, then every other day for two subsequent estrous cycles. Ovulation rates were observed laparoscopically in all ewes 7 d after CIDR removal. Ovulation rates were also observed in BG2 and BG3 ewes approximately 7 d after their second observed estrus, and BG3 ewes again 7 d after the third estrus. One control ewe was removed from the trial after the first laparoscopy because she had lost her CIDR and no corpora lutea (CL) were observed. A 0 h ewe was later removed because of failure to cycle at the first or second laparoscopic observation and the ovaries appeared abnormal. After the first laparoscopic evaluation, BG 2 ewes were placed with fertile rams. BG3 ewes were placed with fertile rams after the second laparoscopy. Ewes were lambed in confinement. Birth type, birth date, sex, dam, and birth weight were recorded.

A second experiment with 96 Rambouillet ewes was conducted in the fall of 1995. Ewes (108.8 $\pm$ 1.9 lb) were randomly assigned and balanced for age (3- or 6-yr-old) to two treatments (control, 0 h) for passive immunization. Method of immunization, dosage of antibody, and estrus synchronization were the same as the first experiment. At CIDR removal, 0 h ewes were

passively immunized against inhibin and all ewes (control, 0 h) were placed with 15 rams. Eleven rams were fitted with marking harnesses to aid in estrus detection. Ovulation rates were observed laparoscopically only for the first estrus 9 d after CIDR removal.

Blood Samples

Experiment 1

Blood samples were collected by venipuncture in 13 ml vacuum tubes. Samples were collected from all treated ewes 24 h after immunization and all control ewes at CIDR removal. Serum was separated and stored at -4 °C for determination of antibody titers and FSH in all ewes. Eight animals randomly selected from each treatment were bled weekly until the third ovulation rate was observed. The same animals were bled each time.

Experiment 2

All ewes were sampled a single time, 24 h after CIDR removal. Blood collection, serum separation and storage were conducted the same as in Experiment 1.

Statistical Analysis

Statistical analysis of data were performed using the GLM procedure of SAS (1992). The model used (Experiment 1) to estimate treatment differences for anitbody titer, FSH, and all reproductive traits included the fixed effect for treatment and a linear covariate for body weight at breeding. Breeding group and breeding group x treatment interactions were also evaluated for fertility and prolificacy. Preliminary analysis showed no significant effect of breeding group or interactions in prolificacy; however, breeding group had a significant effect on fertility. Treatment means were estimated for serum concentrations and reproductive performance when adjusted to the mean body weight of all animals.

The model used to estimate treatment differences in Experiment 2 for antibody titer and reproductive traits included a fixed effect for treatment by age and a covariate for breeding weight within treatment. Treatment means were estimated at the mean body weight of all ewes (108.8 lb).

Results and Discussion

Experiment 1

Antibody titers (Tables 1 and 2) of immunized ewes increased tenfold over the control ewes within 24 h of immunization and remained higher ($P < .01$) than controls throughout the sampling period (42 d). Antibody levels declined steadily after the observed 24 h post injection peak. Antibody titers and FSH were similar for animals treated 48, 24 or 0 h before CIDR removal. FSH levels of immunized ewes were higher ($P < .01$) than control ewes 24 h after antibdy injection but were comparable to control ewes 7 d after CIDR removal.

Table 1. Least squares means of blood serum antibody titer and FSH from ewes sampled 24 hours after immunization with an inhibin antibody

	Antibody Titer RP-2 Units			FSH ng/ml		
	LS Mean (n = 23)	LS Mean (n = 71)	P	LS Mean (n = 23)	LS Mean (n = 71)	P
Control vs Immunized	31.48 ± 4.29	338.48 ± 2.44	.01	13.32 ± 1.04	19.79 ± 0.59	.01
0 h vs -24 h	340.97 ± 4.29	336.19 ± 4.20	.43	20.27 ± 1.04	20.17 ± 1.02	.94
0 h vs -48 h	340.97 ± 4.29	338.00 ± 4.20	.62	20.27 ± 1.04	18.91 ± 1.02	.35

Table 2. Least square means of blood serum antibody titer and FSH from ewes passively immunized against inhibin and sampled weekly after CIDR removal

	Antibody titer RP-2 units			FSH ng/ml		
Days after CIDR removal	Control (n = 8)	Immunized (n= 24)	P	Control (n =8)	Immunized (n=24)	P
7	27.22 ± 11.69	253.31 ± 6.76	.01	17.26 ± 1.64	17.27 ± 0.95	.99
14	23.40 ± 7.00	192.37 ± 4.04	.01	13.97 ± 1.40	17.77 ± 0.81	.03
21	17.92 ± 5.61	151.49 ± 3.24	.01	11.52 ± 1.10	11.31 ± 0.64	.87
28	10.65 ± 7.21	109.49 ± 4.16	.01	14.95 ± 1.45	13.29 ± 0.84	.33
35	10.29 ± 6.01	90.02 ± 3.47	.01	9.74 ± 1.75	11.24 ± 1.01	.74
42	24.75 ± 8.26	76.70 ± 4.77	.01	14.44 ± 2.29	16.17 ± 1.32	.51

Days to first estrus (Table 3) were not different for control vs treated ewes. Ovulation rate of immunized ewes was increased 96% (3.18 vs 1.62) as compared to controls during the first estrous cycle after antibody injection. Ewes treated 24 h prior to CIDR removal had a greater (P = .05) ovulation rate (3.74) than ewes treated 48 h prior (2.99) to CIDR removal or ewes treated at (2.83) CIDR removal. Ovulation rate at the second estrus was similar for control and treated ewes. At the third estrus, the immunized ewes ovulated significantly fewer (16.7%) ova than control ewes. One possible explanation is that the increased ovulation rate after the first estrus may lead to a period of below average reproductive performance as antibody titers decline. This has been suggested in earlier work (Willingham et al., 1991) which was done with active immunization against androstenedione where a nonsignificant decline in lamb production was observed. Further work needs to be conducted to determine if this decline in ovulation rate is repeatable and if so, the duration of the negative effect of immunization on ovulation. This is particularly important if a producer were to passively immunize ewes for out of season or fall lambs, followed by re-exposure of ewes for winter or spring lambs.

Fertility, prolificacy, and the number of lambs born per ewe exposed, did not differ (Table 4) for passively immunized ewes when compared to control ewes. The failure of increased ovulation rate to be realized as increased number of lambs born, and subsequently raised, is not readily explained by these data. It has been well documented (Casida et al. 1966; Dolling and Nicolson, 1967) that as ovulation rate increases, reproductive wastage increases but generally at a lower rate for many different reasons.

Table 3. Least squares means of days to first estrus and ovulation rate at three consecutive cycles

	n	LS Mean	n	LS Mean	P
Days to first estrus					
Control vs Treat	22	1.86 ± 0.21	65	1.86 ± 0.12	.99
0 h vs -24 h	22	2.04 ± 0.21	23	1.43 ± 0.21	.04
0 h vs -48 h	22	2.04 ± 0.21	20	2.10 ± 0.22	.85
First ovulation rate					
Control vs Treat	23	1.62 ± 0.28	71	3.18 ± 0.16	.01
0 h vs -24 h	23	2.83 ± 0.28	24	3.74 ± 0.27	.02
0 h vs -48 h	23	2.83 ± 0.28	24	2.99 ± 0.27	.67
Second Ovulation rate					
Control vs Treat	15	1.94 ± 0.10	47	1.78 ± 0.06	.20
Third ovulation rate					
Control vs Treat	8	1.98 ± 0.14	24	1.65 ± 0.08	.05

Table 4. Least squares means reproductive performance of ewes passively immunized against inhibin

	n	LS Mean	n	LS Mean	P
Fertility					
Control vs Treat	23	0.70 ± 0.09	71	0.73 ± 0.05	.75
0 h vs -24 h	23	0.78 ± 0.09	24	0.62 ± 0.09	.21
0 h vs -48 h	23	0.78 ± 0.09	24	0.79 ± 0.09	.96
Lambs born per ewe exposed					
Control vs Treat	23	1.22 ± 0.18	71	1.21 ± 0.10	.97
0 h vs -24 h	23	1.30 ± 0.18	24	1.04 ± 0.18	.31
0 h vs -48 h	23	1.30 ± 0.18	24	1.29 ± 0.18	.96
Prolificacy					
Control vs Treat	16	1.74 ± 0.14	52	1.68 ± 0.08	.69
0 h vs 24 h	18	1.69 ± 0.13	15	1.69 ± 0.14	.98
0 h vs -48 h	18	1.69 ± 0.13	19	1.64 ± 0.12	.80

Results of Experiment 2 are shown in Table 5 and support the general conclusions of the Experiment 1. Antibody titers increased markedly within 24 h after passive immunization while days to estrus, fertility, lambs per ewe exposed and prolificacy were not affected by immunization. FSH has not been evaluated at present. The immunized 3-yr-old ewes had a significantly higher ovulation rate (2.14 vs 1.28) than the 3-yr-old control ewes. However, the ovulation rate of the 6-yr-old immunized ewes was not significantly different (1.79 vs 1.73) from the 6-yr-old control ewes.

The mean body weight did not differ among the treatment by age cells. However, the 3-yr-old ewes did weigh less than the 6-yr-old ewes (97.2 lb vs 126.4 lb). The estimated regression coefficients for body weight were .014 and .001, for the treated and control groups, respectively. The difference between these regressions coefficients was not significantly different from zero (P = .39). However, the nonsignificant difference between the body weight within treatment regression coefficients and the effect of immunization across age indicate that immunization had a larger effect at heavier body weights. The relationship between treatment and body weight is shown in Figure 1. The estimated effect of immunization at 100 lb body weight was an increase of .34 ± .26 ova (P = .20) The estimated effect of immunization at 130 lb body weight was an increase of .75 ± .34 ova (P = .03). However, it should be remembered that this increase in ovulation rate is not resulting in a significant increase in lambs produced. The data from these two experiments suggest that the effect of passive immunization with an inhibin antibody can increase ovulation rate. The results of Experiment 2 suggest that the effect is greater in younger ewes (3-yr-old vs 6-yr-old) and the effect is greater at higher body weights.

Figure 1. Relationship of ovulation rate to body weight by treatment.

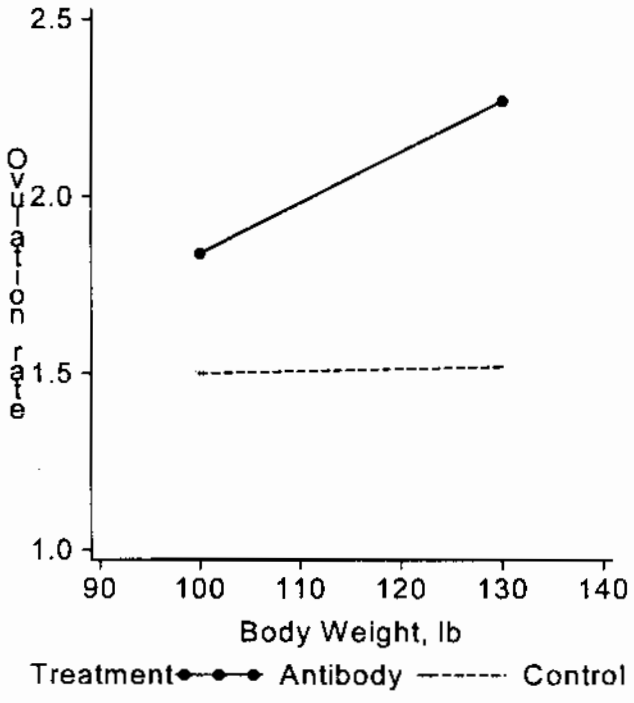


Table 5. Antibody titers and reproductive performance of 3- and 6-yr-old Rambouillet ewes (Experiment 2).

Treatment	Age, yr	n	Antibody titer RP-2 units
Immunized	3	29	154.36[a] ± 5.93
Immunized	6	19	162.50[a] ± 8.07
Control	3	29	0.69[b] ± 5.65
Control	6	19	0.89[b] ± 7.66

Treatment	Age, yr	n	Days to estrus	n	Ovulation rate
Immunized	3	26	1.50[a] ± .12	29	2.14[a] ± .21
Immunized	6	18	1.95[a] ± .16	19	1.79[ab] ± .29
Control	3	27	1.63[a] ± .12	29	1.28[b] ± .20
Control	6	19	1.52[a] ± .15	19	1.73[ab] ± .27

Treatment	Age,yr	n	Fertility	Lambs per ewe exposed	n	Prolificacy
Immunized	3	29	.63[a] ±.12	.83[a] ± .19	15	1.31[a] ± .21
Immunized	6	19	.41[a] ±.16	.63[a] ± .27	11	1.49[a] ± .26
Control	3	29	.46[a] ±.11	.59[a] ± .19	14	1.30[a] ± .20
Control	6	19	.83[a] ±.15	1.21[a] ± .25	15	1.45[a] ± .19

Implications

The use of passive immunization against inhibin caused a marked increase in antibody titers and FSH, with FSH concentrations declining rapidly while titers declined gradually. Passive immunization improved ovulation rate yet failed to improve fertility, lambs per ewe exposed or prolificacy, in Rambouillet ewes maintained under extensive Texas range conditions.

Literature Cited

Burger, H.G. 1988. Inhibin: definition and nomenclature, including related substances. J. Endocrinology 117:159.

Casida, L.E., C.O. Woody, and A.L. Pope. 1966. Inequality in function of the right and left ovaries and uterine horns of the ewe. J. Anim. Sci. 25:1169.

Dolling, C.H.S., and A.D. Nicolson. 1967.Vital statistics for an experimental flock of Merino sheep. IV: Failure in conception and embryonic loss as causes of failure to lamb. Aust. J. Agric. Res. 18:767.

Kusina, N.T., R.L. Meyer, K.M. Carlson, and J.E. Wheaton. 1995. Effects of passive immunization of ewes against an Inhibin-peptide on gonadotropin levels, ovulation rate, and prolificacy. Biol. Reprod. 52:878.

Meyer, R.L., K.M. Carlson, J. Rivier, and J.E. Wheaton. 1991. Antiserum to an Inhibin alpha-chain peptide neutralizes Inhibin bioactivity and increases ovulation rate in sheep. J. Anim. Sci. 69:747.

Shelton, Maurice. 1980. Factors affecting efficiency of lamb production. In: Sheep and Goat handbook. 1:348.

Willingham, T.D., M. Shelton, and P. Thompson. 1991. The efficacy of Fecundin in improving reproduction in Rambouillet ewes. SID Sheep Res. Jour. 7:11.

Ying, S.-Y. 1988. Inhibins, activins and follistatins: gonadal proteins modulating the secretion of follicle-stimulating hormone. Endocrine Reviews. 9:267.

Evaluation of the Accuracy of Central Performance Test Data in Rambouillet Sheep

D.F. Waldron, P.V. Thompson, W.S. Ramsey, T.A. Taylor, M. Salisbury, and G.R. Engdahl

ABSTRACT

A progeny test of nine centrally tested Rambouillet rams was conducted. The postweaning central performance test was 140 d long. Traits evaluated on the central test included average daily gain, fleece weight and fleece fiber diameter. Progeny were evaluated for birth weight, weaning weight, postweaning weights and postweaning gain. Progeny performance was regressed on sire's central test performance. Increased average daily gain on central test resulted in progeny with significant ($P < .05$) increases in weaning weight and postweaning gains of lambs on feed. Increased average daily gain on central test did not result in increased progeny birth weight. Increased average daily gain on central test resulted in positive, but nonsignificant ($P > .10$) increases in postweaning weights of ewe (6 mo and 10 mo) and wether (7 mo) progeny. Data from additional sires and traits will be collected in this ongoing project.

Introduction

A central performance test of Rambouillet rams has been conducted annually at the Sonora Station since 1948 (Shelton, 1979). A purpose of such a central performance test is to allow for valid comparisons of performance of animals from different ranches. Performance differences observed on different ranches can be due to genetic differences as well as environmental differences. When evaluating breeding stock, it is desirable to separate genetic differences, that will be passed on to progeny, from environmental differences, that will not be passed on to progeny. The practice of measuring performance of animals from several different ranches at one central location has been employed to remove environmental differences. If the performance of rams during the test is not influenced by pretest environment, the differences observed are genetic differences. Research work conducted during the early years of the Sonora test (Shelton, 1959) showed a positive relationship between central test performance and progeny performance, indicating that the test practices were successful in identifying genetically superior rams.

Test practices have changed since the 1950s. Some of the central tests used in the 1959 report were 308 d long. The test has been 140 d long since 1972. A study conducted with Suffolk rams from Midwest central performance test stations in the 1980s showed no significant relationship between central test performance and progeny performance for post weaning growth rate (Waldron et al., 1990). The central tests in the Midwest study were only 63 d long, which is typical of many central performance tests in the Midwest (Waldron et al., 1989).

Self feeders are used at the Sonora central test so that performance is not limited by available nutrition. Because of the high level of nutrition, performance for traits such as growth rate and fleece weight are higher than what would be expected under range conditions. The objective of this study was to estimate the relationship between performance observed during the 140-d central performance test and subsequent progeny performance under commercial conditions. This report gives results on growth traits for the first phase of a three-phase project.

Materials and Methods

Each phase of this project includes obtaining rams from the central performance test, mating them to ewes the next breeding season, evaluating growth rate of progeny as lambs, and evaluating fleeces of progeny as yearling ewes and 2-yr-old ewes. Nine unrelated rams that completed the Sonora Central Performance Test in February 1994 were chosen to be used in the first phase. The rams were chosen so that a wide range of performance was represented for average daily gain (ADG), clean fleece weight (CFW) and fiber diameter (FD). The range of performance among the 203 rams that finished the test and the nine rams selected for the progeny test are shown in Table 1.

Table 1. Mean, minimum and maximum of performance measures on central test

Trait	No.*	Mean	Minimum	Maximum
ADG, lb/d	N = 203 n = 9	.72 .79	.44 .56	1.07 .99
Clean fleece wt., lb/yr	N = 203 n = 9	11.5 12.2	6.3 9.1	19.2 15.3
Fiber diameter, μm	N = 203 n = 9	23.7 23.8	17.8 20.2	29.6 27.0

*203 rams finished the central test, 9 rams were chosen for the progeny test.

A flock of 3-yr-old, commercial Rambouillet ewes on the Winters Ranch near Brady, Texas were mated in single sire pastures in September 1994. All lambs were weighed at birth and at weaning, June 26, 1995, at an average age of 135 d. The ewe lambs were raised on pasture with some supplemental feed. Postweaning weights were obtained on the ewe lambs at 6 and 10 mo of age. The ewe lambs were shorn on August 7, 1995, so that the fleeces obtained in 1996 would all have the same period of growth. No analyses were done on the fleeces shorn at an average age of 6 mo.

Ram lambs were visually appraised and ranked at 60 d of age by an experienced livestock evaluator. The five highest ranked lambs were left as intact males and the remainder were castrated. At weaning, the wether lambs were taken to the Texas A&M sheep center at College Station, Texas, shorn and started on feed. They were fed *ad libitum* a diet that was 15% crude protein and 67% TDN. Lambs were slaughtered in four groups with the heavier lambs slaughtered after 49 d on feed. The traits analyzed were weight after 49 d on feed, approximately 7 mo of age, and ADG during the 49 d on feed. The ram lambs were part of another experiment where the lambs were self-fed the same diet as was fed at the Sonora Central Performance Test. This trial was conducted at Angelo State University, San Angelo, Texas. The rams were shorn October, 1995 and again 140 d later in February, 1996.

Growth rates and body weights were analyzed with PROC MIXED (SAS, 1992). Sire of the lambs was fit as a random effect, sire's central test performance was fit as a covariate (Henderson, 1984). All other effects were fit as fixed effects. The partial regression coefficients of progeny performance on sire's central test performance were used to evaluate the relationship between progeny performance and sire's central test performance.

Results

The results of the regressions of various progeny weight and growth traits on sire's central test performance are presented in Table 2.

Birth weight

The regression of progeny birth weight on sire's ADG on central test was not significantly different from zero. This observation indicates that selecting for increased postweaning ADG on central test does not result in a correlated increase in birth weight.

Weaning weight

The regression of progeny weaning weight on sire's ADG on central test was significantly different from zero. The regression coefficient of 10.7 indicates that for each .1 lb increase in sire's ADG on central test, progeny weaning weight increased by 1.07 lb/lamb.

Postweaning, ewes

The regression of ewe progeny postweaning weights at 6 and 10 mo of age had significance levels of .15 and .13, respectively. The regression coefficients were positive, indicating that rams that had higher ADG on central test, sired ewe lambs that were heavier at 6 and 10 mo of age. However, the low significance levels indicate that the relationship between postweaning ewe lamb progeny weight under pasture conditions and sire's ADG was not strong.

Postweaning, wethers

The regression of wether postweaning weight at 7 mo of age was similar to that of the ewe postweaning weight in that the significance level was .13. The regression coefficient was positive (26.3 lb) , but had a large standard error (17.0 lb). This indicates that for each .1 lb increase in sire's ADG on central test, wether

Table 2. Partial regression coefficients (b) ± SE of progeny performance on sire's central test performance

Progeny trait	Sire trait	N	b ± SE	P
Birth weight	ADG	233	.04 ± .75	.90
Weaning weight	ADG	205	10.7 ± 5.8	.07
Ewe lambs				
Weight at 6 mo	ADG	102	10.8 ± 7.5	.15
Weight at 10 mo	ADG	102	10.1 ± 6.6	.13
Wether lambs				
Weight at 7 mo	ADG	56	26.3 ± 17.0	.13
ADG	ADG	56	.24 ± .11	.04
Ram lambs				
Weight at 12 mo	ADG	35	83.1 ± 30.0	.01
140 d postweaning ADG	ADG	35	.43 ± .12	.01

postweaning weight increased by 2.63 lb/lamb. The regression of wether postweaning ADG on sire's ADG on central test was significantly different from zero. The regression coefficient of .24 indicates that for each .1 lb increase in sire's ADG on central test, wether postweaning ADG increased by .024 lb. Postweaning ADG was measured on the progeny for 49 d. Another way to express this is that for each .1 lb increase in sire's ADG on central test, wether postweaning gain increased by 1.18 lb/lamb (.024 x 49 d = 1.18).

Postweaning rams

The regression of ram progeny weight at 12 mo of age was significantly different from zero. Each .1 lb increase in sire's ADG on central test, resulted in an average increase of 8.3 lb/ram lamb at 12 mo of age. The regression of ram progeny postweaning ADG on sire's ADG on central test was also significantly different from zero. Each .1 lb increase in sire's ADG on central test, resulted in an average increase of .043 lb in ram progeny ADG.

Discussion

The general inference that can be drawn from the results in Table 2 is that the relationship between central test performance and progeny performance is positive. Central test performance was a better indicator of progeny performance when progeny were raised in an environment similar to that of the central test. However, the number of rams with progeny (9) that have been evaluated is not adequate for conclusions. A second set of central performance tested rams have produced lambs born in 1996 and a third set of rams will be mated to produce lambs in 1997. Wool quantity and quality measures will also be evaluated.

Implications

Preliminary results suggest that performance on the 140 d Sonora Central Ram Performance Test is positively related to progeny weaning weights, postweaning weights and ADG. A central performance test can provide meaningful across-flock comparisons of animals for traits that can be measured in young rams.

Literature Cited

Henderson, C.R. 1984. Applications of Linear Models in Animal Breeding. p 331. Univ. of Guelph Press, Guelph, Can.

SAS. 1992. SAS Technical Report P-229. SAS/STAT Software Changes and Enhancements, Release 6.07. SAS Institute Inc., Cary, N.C.

Shelton, M. 1959. Selection of fine-wool rams based on record of performance data. J. Anim. Sci. 18:925.

Shelton, M. 1979. Estimation of genetic change in a performance testing program for sheep. J. Anim. Sci. 48: 26.

Waldron, D. F., D. L. Thomas, J. M. Stookey, T. G. Nash, F. K. McKeith and R. L. Fernando. 1990. Central ram tests in the Midwestern United States: III. Relationship between sire's central test performance and progeny performance. J. Anim. Sci. 68:45.

Waldron, D. F., D. L. Thomas, T. W. Wickersham, D. G. Morrical, S. R. Baertsche, R. E.Hudgens, C. W. Hirschinger and R. A. Kemp. 1989. Central ram tests in Midwestern United States: I. Description and estimation of performance trends. J. Anim. Sci. 67:1189.

The Use of a DNA Marker to Select Sheep for Increased Ovulation Rate

D.F. Waldron, E. Gootwine, T.D. Willingham, and G. Montgomery

ABSTRACT

Ovulation data was analyzed according to DNA marker (OarAE101) genotype in three half-sib families of Booroola-Rambouillet ewes. One of the sires was heterozygous at the marker locus. An estimate of the effect of FecB was 1.2 $\pm$ .25 ova based on the 16 daughters in the informative sire family. The mean ovulation rate of the daughters of the two sires that were homozygous at the marker locus was 2.4.

Introduction

In the early 1980s Booroola-Merino sheep became available in the U.S. The Booroola-Merino was of interest because it had the ability to produce approximately 100% more lambs/ewe lambing than Rambouillet ewes. Unlike the Finnsheep and other prolific breeds, the Booroola-Merino's extra lambs resulted from the effect of a single gene (Davis et al., 1982). The fact that the extra lambs are a function of a single gene, rather than multiple genes, is significant because through crossing and backcrossing Booroola-Merino with other breeds and subsequently selecting for desirable production characteristics, it is possible to transfer, or introgress, the fecundity gene of the Booroola (FecB) into the breed of choice. In Texas range sheep production, the traditional breed of choice is the Rambouillet. In the mid 1980s a research project was initiated at the Texas Agricultural Experiment Station at San Angelo to evaluate Booroola-Merino x Rambouillet cross ewes relative to Rambouillet ewes. The early reports of this research showed that although the Booroola-cross ewes produced more lambs, because of a higher ovulation rate, Booroola-cross ewes were smaller and their lambs did not grow as fast as Rambouillet lambs (Willingham et al., 1988). However, this early project compared the Rambouillet to the Booroola-Merino, The results were partly a function of FecB and partly a function of the particular Merino genetics.

Individual animals may have zero, one or two copies of the gene (FecB) which is responsible for the increased number of lambs born. Ewes with two copies of FecB sometimes produced litters of four or more lambs. Lambs born in larger litters had markedly lower survival. Ewes with one copy of FecB usually had twins or triplets and rarely had litters of four or more. Therefore, the purpose of this project became to make further crosses and selections so as to produce ewes with a high percentage of Rambouillet parentage that still carry FecB. Until recently, the only methods that could differentiate between ewes that did or did not carry the FecB were to count ovulations by laparoscopy or count numbers of lambs born. There was no direct test for rams. A ram's status for FecB could only be determined by observations on reproduction of his daughters.

The science of molecular genetics has made dramatic advances during the life of this project. In 1993 it was reported (Montgomery et al., 1993) that a DNA marker had been found that was linked to FecB. Linked, in this context, means that the marker locus and the FecB locus are in the same region on the same chromosome. Thus, the DNA marker can be used to predict which animals were carrying zero, one or two copies of FecB, provided that 1) the parents of the animals are known, 2) DNA from the parents had been analyzed and 3) the status of the parents for FecB was known. Each animal has two alleles at the marker locus, one inherited from the sire and one inherited from the dam. The different alleles at the marker locus are designated by letters (A,B,C,D,E,...). Therefore, an animal's genotype is designated by two letters such as, EG or EE. Determining an animal's genotype at the marker locus involves obtaining a blood sample from the animal, extracting DNA from the white blood cells (Montgomery and Sise, 1990) and analyzing the DNA by Polymerase Chain Reaction (PCR) to determine which alleles are present in that animal. The DNA marker locus (OarAE101) that was used in this project has been estimated to be 13 cM away from the FecB locus (Montgomery et al., 1993). Therefore, the marker information will allow correct prediction of an animal's FecB status 87% of the time. However, the advantage of using this DNA marker is that the evaluation can be made on lambs before they reach reproductive age.

The Booroola-Rambouillet flock at San Angelo has a mixture of ewes with zero, one or two copies of FecB. These ewes also have a wide range of Rambouillet parentage. In order for the DNA marker data to be useful, the FecB status of some animals must be determined. This was done by progeny testing three rams. The three rams were mated, in July 1994, to purebred Rambouillet ewes from a flock that had no ewes carrying FecB. The female progeny in the three half-sib families were used in the progeny test. The purpose of this report is to present results of this progeny test.

In June and July of 1995, blood samples were obtained from the sires and the ewe lamb progeny of the three half-sib families. DNA was extracted from the white blood cells, stored in ethanol at San Angelo and sent to the Volcani Center in Bet Dagan, Israel for marker analysis. Genotype at the marker locus was determined on the three rams and their daughters.

In November and December 1995, the three half-sib families of Booroola-Rambouillet ewe lambs were exposed to sterile rams for one estrous cycle and a fertile ram for the subsequent cycle. Rams were fitted with a marking harness and breeding marks and dates were recorded. Ovulation rate was observed and recorded on each ewe approximately 10 d after a breeding mark was recorded. Thus, ovulation rate was determined at two consecutive cycles on all the daughters. The mean of the two ovulation observations and weight at 9 mo of age were analyzed within sire group with PROC GLM (SAS, 1990). The model used marker genotype as a fixed effect.

Results and Discussion

The marker genotypes for the sires and the frequency of genotypes in each sire-group are shown in Table 1. Two of the sires (783 and 822) were homozygous for the OarAE101 marker. The families of the two sires that are homozygous (II) at the marker were not informative for establishing linkage. However, in this instance, the gene frequency within these two families provides an estimate of the gene frequency within the flock of Rambouillet ewes at the FecB locus. Based on these two families, the frequencies were E 10%, G 80% and I 10%. A fourth allele, A, was inherited from one of the dams that was bred to 1088. The 1088 family was not used in calculating the gene frequencies. A larger number of ewes would need to be sampled to get a reliable estimate of the gene frequency at this locus. The ovulation rate data from the 1088 sire family will provide information about the linkage between the OarAE101 and FecB loci. The estimate of frequency of the I allele at the OarAE101 locus of 10% among the Rambouillet ewes, suggests that some of the ewes with the GI genotype in the 1088 family inherited the I allele from the dam rather than the sire. Therefore, when estimating the difference in ovulation rate, within the 1088 family, between the ewes that possess the I allele (EI and GI) and those that do not (AG, EG and GG), it is expected that some (an estimated 10%) of the GI ewes did not receive the I allele from the sire.

The means of two observations/ewe of ovulation rate are shown in Table 2 by genotype within sire group. All daughters of 783 and 822 inherited the I allele. If these rams are also homozygous for FecB, each of their daughters has one copy of FecB. All of the 783 daughters and 90% of the 822 daughters had mean ovulation rates of 2 or more. The ovulation data suggest that 783 and 822 are homozygous for FecB.

Table 1. Frequency of genotypes at OarAE101 locus in three half-sib families*

	Sire, genotype		
	783, II	822, II	1088, GI
Marker genotype			
AG			6% (1)
EG			12% (2)
EI	16% (3)	5% (1)	19% (3)
GG			25% (4)
GI	74% (14)	86%(19)	37% (6)
II	10% (2)	9% (2)	
Total	100 % (19)	100% (22)	100% (16)

* number of daughters in parentheses

Table 2. Mean ovulation rate and (number of ewes observed) by marker genotype within sire families

	Sire, genotype		
	783, II	822, II	1088, GI
Marker genotype			
AG			1.00 (1)
EG			1.50 (2)
EI	2.83 (3)	2.50 (1)	2.50 (3)
GG			1.25 (4)
GI	2.57 (14)	2.29 (19)	2.33 (6)
II	2.50 (2)	1.75 (2)	

In contrast, 44% of the daughters of 1088 had mean ovulation rates less than 2. The groups that are informative for linkage analysis, are those of sire 1088 because he was heterozygous at the marker locus. Analysis of mean ovulation rates of 1088 daughters which carry the I allele vs those that do not carry the I allele yielded an estimate of an increase in ovulation rate of $1.2 \pm .25$ ($P < .01$) associated with the I allele. For the 1088 sire, the I allele is linked to the FecB allele which increases ovulation rate. There was no significant difference in body weight between ewes which inherited either the I allele or the G allele from sire 1088.

The estimate of increased ovulation is similar to that reported by others (Piper et al., 1985) when comparing ewes with one copy of FecB to ewes with zero copies of FecB. The estimate in this report differs from many of the previous reports in that the estimate is based on data from ewes within a group of half-sibs. The use of the DNA marker affords the opportunity to get an estimate of the effect of FecB unbiased by other genetic background effects. Currently more heterozygous rams are being progeny tested and additional DNA markers are being evaluated for accuracy in identifying sheep that are carrying FecB. The use of the marker has allowed for stricter culling on production traits. Therefore the selection progress for superior growth and wool characteristics can be accelerated.

Implications

The use of DNA markers has provided the ability to select lambs for increased reproductive rate before they reach reproductive age. The use of this procedure has limited value when pedigrees are not known. When replacements are selected according to marker genotype, further selections can be made so that improvement in other important production traits can be achieved. Using marker assisted selection will increase the rate of introgression of FecB into Rambouillet sheep.

Acknowledgments

This project was partially supported by a grant from the Texas Department of Agriculture as part of the Texas-Israel Exchange program.

Literature Cited

Davis, G.H., G.W. Montgomery, A.J. Allison, R W. Kelly, and A. R. Bray. 1982. Segregation of a major gene influencing fecundity in progeny of Booroola sheep. N.Z. J. Agric. Res. 25:525.

Montgomery, G.W., A.M. Crawford, J.M. Penty, KG. Dodds, A. J. Ede, H.M. Henry, C.A. Pierson, E.A. Lord, et al. 1993. The ovine Booroola fecundity gene (FecB) is linked to markers from a region of human chromosome 4q. Nature Genetics 4:410.

Montgomery, G.W. and J.A. Sise. 1990. Extraction of DNA from sheep white blood cells. N.Z. J. Agric. Res. 33: 437.

Piper, L.R., B.M. Bindon, and G.H. Davis. 1985. The single gene inheritance of the high litter size of the Booroola Merino. In: R. B. Land (Ed.) Genetics of Reproduction in Sheep. p 115. Butterworths, London.

SAS. 1990. SAS/STAT User's Guide, Version 6, 4th Edition. SAS Inst. Inc., Cary, NC.

Willingham, T., M. Shelton, and C. Lupton. 1988. The influence of introducing the Booroola Merino genotype to Rambouillet flocks on reproduction and fleece traits in comparison with other selected breed crosses. Sheep Res. J. 4:1.

Growth Rate and Feed Efficiency of Boer x Spanish Compared to Spanish Goats

D.F. Waldron, T.D. Willingham, P.V. Thompson, and J. E. Huston

ABSTRACT

Boer x Spanish kids were compared to Spanish kids for pre- and postweaning weights during a 2-yr study. Fifteen Boer sires and eight Spanish sires were represented by a total of 681 progeny. Boer-sired kids were heavier at birth, but this did not result in dystocia. Boer- and Spanish-sired kids were similar in weight ($P > .5$) at 100 d of age. The male kids were randomly assigned to either a high level of nutrition in a feedlot or low level of nutrition on pasture. The Boer-sired kids had greater growth rate ($P < .1$) and greater live weights at 8 mo of age ($P < .1$) in the feedlot. Boer-sired kids had an advantage ($P < .05$) in feed:gain ratio over Spanish-sired kids (6.0 vs 7.5) in the feedlot. Intact male kids had a weight advantage of 9.1 lb over castrated males at 8 mo of age.The Boer-sired kids did not have a consistent, significant advantage in postweaning weights or growth rate when maintained on pasture with little or no supplemental feed. Doe kids had a nonsignificant advantage in weight at 6 and 9 mo of age. Postweaning growth rates indicate Boer-sired kids are physically later maturing.

Introduction

There has been an increased interest in raising goats for meat production during the 1990s. Some of the factors fueling this interest are strength of the market for slaughter goats, the loss of mohair incentive payments, and the desire by ranchers to diversify their operations.

The South African Boer goat has long had a reputation for being an improved breed with respect to increased meat production (Naude and Hofmeyr, 1981; Casey and Van Niekerk, 1988). The Boer is reported to have a large mature size, high growth rate, lean carcass (Van Niekerk and Casey, 1988), and high reproductive rate (Campbell, 1984). There are no published reports where the performance of Boer was directly compared to an alternative meat producing breed that is available to U.S. goat producers. In the Southwestern U.S., the Spanish goat has been used primarily for meat production (Shelton, 1978). Boer germplasm, live animals, embryos, and semen, became available in the U.S. in 1993. The objective of this study was to estimate differences in growth rate and feed efficiency of kids sired by either Boer or Spanish bucks.

Materials and Methods

A herd of Spanish does was used to produce Boer x Spanish (Bx) and Spanish x Spanish (S) kids in March and April of 1994 and 1995. The Spanish does were assigned at random to be bred to either Boer or Spanish bucks. Because of the limited number of Boer bucks and their associated high cost, artificial insemination using thawed frozen semen was used to produce most of the Bx kids on a random sample of the does while the Spanish bucks were naturally mated in single sire pastures. Boer sires were chosen so as to represent a range of performance, live weights up to 1 yr of age, and to minimize relationships between sires. The Boer semen available in the U.S. in 1993 and 1994 was from sires that had been in New Zealand quarantine stations. Performance data were not available on all sires. The Spanish sires that were used were chosen so as to represent a selected sample of bucks. When the Boer became available to U.S. goat producers, two avenues for genetic improvement were 1) use Boer bucks and 2) use selected Spanish bucks. The very high cost of Boer bucks in 1993 and 1994 made the use of highly selected Boer bucks unaffordable for many goat producers. Thus, the comparison in this study was of a representative sample of Boer bucks versus a selected sample of Spanish bucks. The number of does kidding, number of sires, and number of kids born are shown in Table 1 by year and breed.

Table 1. Number of does kidding, sires and records by year and breed of sire

Year	Breed of sire	Does kidding	Sires	Birth wt. records	100 d wt records	Postweaning		
						Males, feedlot records	Males, pasture records	Females, pasture records
1994	Boer	126	6	211	172	43	23	103
	Spanish	97	6	154	133	43	26	71
1995	Boer	86	9	143	127	40	26	57
	Spanish	111	4	173	157	40	32	59

The does were maintained and all kids were born at the Winters Ranch, near Brady, Texas. The kids were paired with their dams and weighed within 24 h of birth. All male kids of the 1994 kid crop were left intact. A random sample, within sire, of the male kids of the 1995 kid crop was castrated at an average age of 87 d. All kids and does were maintained on pasture until approximately 100 d of age. Male kids were weaned from their dams at approximately 100 d of age.

At weaning, male kids were randomly assigned to either pasture or feedlot for the postweaning growth period, approximately 4 to 8 mo of age. An adjustment period of approximately 4 wk was used to get the kids on feed before starting the trials. In 1995, castrated and intact males were assigned to the feedlot whereas only castrated males were assigned to pasture. Thus, the 1994 pasture kids were intact males and the 1995 pasture kids were castrated males. The kids that had been assigned to pasture were not given supplemental feed. The pasture used in 1994 was typical Edwards Plateau rangeland, which had multiple species of grasses and forbs. Low quality and availability of vegetation resulting from low rainfall during the study period provided a low level of nutrition. The pasture used in 1995 provided a higher level of nutrition because of greater rainfall during the study period. The kids that had been assigned to feedlot were fed an 80% concentrate, 14% crude protein diet. The postweaning growth periods were 112 and 100 d, for 1994 and 1995, respectively.

The kids assigned to the feedlot environment were assigned randomly to pens within breed or breedtype. In 1994 there were four pens of each breedtype. In 1995 there were three pens of each breedtype-sex (intact or castrated) combination. Feed intake was recorded for each pen. Feed consumed was expressed as a percentage of the average live weight of the kids in the pen. A feed:gain ratio was computed by dividing feed consumed by weight gain per pen.

The female kids were left with their dams on pasture until weaning at approximately 5 mo of age. At weaning the female kids were maintained on pasture with some supplemental feeding when pasture conditions deteriorated. Postweaning weights were recorded at 6 and 9 mo of age.

Statistical Analyses

Weight data were analyzed with PROC MIXED (SAS, 1992). Birth and 100 d weight were analyzed using data from both years in one analysis. The model included fixed effects for year, breed of sire, sex, type of birth, a random effect for sire within breed, and a covariate for date of birth within year (for birth weight) or age at weaning (for 100 d weight). Postweaning traits were analyzed within year because of the different circumstances across years. The model used to analyze the weights and gains of the feedlot kids also included a random effect for pen. Feed consumption and feed:gain were analyzed on a pen basis using data from both years. The model included fixed effects for year, breed of sire, and sex within year. Feed consumption and efficiency data were analyzed with PROC GLM (SAS, 1990).

Results

The results of the birth weight analysis in Table 2 show that Bx kids were significantly heavier at birth. The higher birth weights of the Boer kids did not result in increased dystocia. The average weight of the Spanish dams was 82 lb at the beginning of the breeding season. This suggests that the increased birth weight of Bx kids was not a problem for these average size Spanish does. The birth weight difference was maintained through to 100 d of age. However, due to the increased variation in 100 d weight compared to birth weight, the difference was not significant at 100 d of age.

The different postweaning environments used for the males resulted in substantial differences in variances (Table 3). The most obvious differences were observed in the 1994 trial, where at 8 mo of age, the feedlot kids weighed nearly twice as much as their half-sib contemporaries that had been assigned to pasture. Although the same diet was fed to the feedlot kids in 1994 and 1995, a different barn was used with a different style of feed trough. Because there were several factors that were different, sires, weather, barn, etc., a conclusion about why the feedlot performance was greater in 1994 as compared to 1995 would be speculative. Despite the difference in the absolute level of performance in the feedlot, the advantage of Bx over S was similar across years. Under feedlot conditions, Bx kids were 8.9 and 8.6 lb heavier than S kids at 8 mo of age, in 1994 and 1995, respectively. This was primarily a result of the superior growth rate (.08 lb/d) of the Bx kids during the postweaning feeding phase.

Table 2. Least squares means ± (SE) of breed of sire for birth and 100 d weights

Trait	Boer	Spanish	Boer - Spanish	P
Birth weight, lb	6.35 ± .10	5.98 ± .12	+.37 ± .14	.01
100 d weight, lb	36.7 ± .74	36.3 ± .62	+.37 ± .64	.56

The 1995 feedlot data included intact and castrated Bx and S males. At 8 mo of age the intact males were heavier (9.1 ± 3.0 lb, P = .01) than castrated males. Part of this weight advantage existed at the start of the postweaning trial because castration was done 7 wk prior to the start of the postweaning growth trial. The intact males had a nonsignificant advantage in growth

rate (.042 ± .024 lb/d) over the castrated males during the postweaning growth period.

Under pasture conditions, the performance of the 1994 kids was not comparable to the performance of the 1995 kids because of the difference in level of nutrition provided by the pastures. The ADG of the pasture kids in 1994 was very low and not different between breed of sire. The ADG of the 1995 kids on average pasture was intermediate to the ADG of the feedlot kids and that of the 1994 pasture kids. The Bx kids on pasture in 1995 had an ADG advantage ($P < .1$) over their S contemporaries.

The results in Table 3 for 8 mo weight on pasture appear to contradict the results for ADG on pasture. The 1994 pasture Bx kids were heavier ($P = .06$) but did not gain faster ($P = .93$), whereas the 1995 pasture kids were not heavier ($P = .66$) and did gain faster ($P = .09$). This is merely a sampling effect. The kids were assigned to pasture or feedlot at random within sire. Further analysis showed that, at the start of the postweaning growth trial, within the sample of kids assigned to pasture, the Bx kids were nonsignificantly heavier than the S kids in 1994 and nonsignificantly lighter than the S kids in 1995. Therefore, the Bx kids weight advantage on pasture in 19964 was due to a higher weight at the start of the postweaning trial.

The Bx kids consumed more feed, as a percentage of live weight, than S kids (Table 4). However, the higher postweaning growth rate of the Bx feedlot kids (Table 3) resulted in a better postweaning feed:gain ratio for Bx as compared to S.

The growth rates of the doe kids from 6 to 9 mo of age are shown in Table 5. There was not a significant breed of sire effect on live weight at 6 or 9 mo of age in the doe kids maintained under range conditions. However, the growth rate of the Bx kids was greater ($P = .06$ in 1994 and $P = .11$ in 1995) than that of the S kids from 6 to 9 mo of age.

Table 3. Least squares means ± (SE) of breed of sire for postweaning traits measured in male goat kids

Trait	Boer	Spanish	Boer - Spanish	P
8 mo wt, lb feedlot - 1994	83.0 ± 3.26	74.0 ± 3.88	8.9 ± 4.50	.10
8 mo wt, lb feedlot - 1995	68.4 ± 2.96	59.8 ± 3.56	8.6 ± 4.55	.09
8 mo wt, lb pasture - 1994	44.0 ± 1.77	39.5 ± 1.86	4.4 ± 2.11	.06
8 mo wt, lb pasture - 1995	54.8 ± 1.52	55.9 ± 1.45	- 1.0 ± 2.28	.66
ADG, feedlot - 1994	.37 ± .02	.29 ± .03	.08 ± .04	.08
ADG, feedlot - 1995	.25 ± .02	.17 ± .02	.08 ± .03	.03
ADG, pasture - 1994	.01 ± .01	.01 ± .01	-.01 ± .01	.93
ADG, pasture 1995	.13 ± .01	.10 ± .01	.03 ± .01	.09

Table 4. Least squares means ± (SE) of feed consumption and efficiency by breed of sire

Trait	Boer	Spanish	Boer - Spanish	P
Feed consumption, % of live weight/d	3.15 ± .06	2.87 ± .06	.28 ± .08	.003
Feed:gain	6.0 ± .42	7.5 ± .42	-1.5 ± .59	.02

Table 5. Least squares means ± (SE) of breed of sire for postweaning traits in female kids

Trait	Boer	Spanish	Boer - Spanish	P
6 mo wt, lb - 1994	39.4 ± 1.04	40.3 ± 1.18	- 1.0 ± 1.39	.51
9 mo wt, lb - 1994	47.4 ± .87	46.1 ± 1.04	1.4 ± 1.16	.26
ADG, 6 to 9 mo - 1994	.09 ± .01	.06 ± .01	.03 ± .01	.06
6 mo wt, lb - 1995	35.2 ± 1.31	35.8 ± 1.33	-.6 ± 1.79	.75
9 mo wt, lb - 1995	43.5 ± 1.24	41.9 ± 1.27	1.5 ± 1.69	.39
ADG, 6 to 9 mo - 1995	.08 ± .01	.06 ± .01	.02 ± .01	.11

Discussion

The preweaning data indicated that the Bx kids did not have a significant weight advantage at 100 d of age when raised under range conditions. If kids are to be marketed for slaughter at 100 d of age or less, the potential of the Bx kids will not be realized fully. The postweaning results show that Bx kids have an advantage over S kids in growth rate at a high level of nutrition. The advantage of the Bx kids (.08 lb/d) can be realized if the kids are provided with a postweaning level of nutrition that will allow them to express their genetic potential for growth. When postweaning nutrition level was low (1994 pasture), no difference in growth rate was observed between Bx and S kids. The 1995 pasture conditions were superior to the 1994 pasture conditions, and the postweaning growth rate of the Bx kids was superior ($P < .1$) to that of the S kids in 1995.

Blackburn (1995) published results of a computer simulation study where the biological efficiency of Boer was greater than Spanish in situations where nutrition was not limiting. A similar result was obtained in the present study. However, the simulation result was a function of female reproduction, whereas the present study does not address reproduction.

The estimates of feed:gain ratio in the present study (6.0 and 7.5) were less than those of a study that used Alpine and Nubian kids (Lu and Potchoiba, 1990) from 17 to 32 wk of age. They reported estimates of feed:gain ratios of 9.3 and 8.6 using dry matter intake:gain for diets of 12.7 and 15.1% CP, respectively. The CP level of the present study was intermediate to these levels.

The postweaning data from the female kids, which were on pasture, indicate that Bx kids are physically later maturing than S kids. In both years, the S kids had a nonsignificant weight advantage at 6 mo and the Bx kids had a nonsignificant weight advantage at 9 mo. The female kids were not on a high level of nutrition, as is evident by comparing the growth rate of the females to that of their male half-sibs. The data from the male kids indicate that the potential growth rate advantage of Bx over S will not be realized on a low level of nutrition. The breed of sire comparison in the females is therefore applicable to the conditions under which the kids were grown and should not be generalized to other situations where a higher level of nutrition is available. The results presented here are applicable to West Texas range conditions.

The potential growth rate advantages of Bx kids over S kids can be realized economically if the market will pay financial rewards for heavier kids at the same age or younger kids at the same weight. The profitability of feeding goats is a function of growth rate, feed conversion and market rewards for increased weight. The feed efficiency results showed that Bx kids had an advantage in a feedlot environment.

If male goats are to be maintained past puberty in the breeding season, castration is a management option that will eliminate rutting behavior. The consequence of castration at 3 mo of age was estimated to be a disadvantage of 9.1 lb of body weight at 8 mo of age.

Implications

What impact the Boer goat will have on the meat goat industry will ultimately be a function of its ability to produce a profit. The postweaning data from these studies demonstrate that, when nutrition is not a limiting factor, Boer-sired kids exhibited a higher growth rate than Spanish-sired kids. The advantage of the Boer-sired kids in postweaning growth rate was realized during the latter part of the feeding trial. This suggests that for meat goat producers to realize the full benefit of using faster growing Boer bucks, kids will have to be marketed at older ages (6 to 8 mo) and/or heavier weights (>60 lb liveweight).

Acknowledgments

This project was supported in part by loans of Spanish bucks from Tom Carter, Stan and Kay Keen, Robert Kensing, and Jim Willingham and gifts of Boer semen from Landcorp Farming (Canada) Limited, Don Smith and T4 Ranch (W.E. Whitehead). Their support of our research program is greatly appreciated.

Literature Cited

Blackburn, H. D. 1995. Comparison of performance of Boer and Spanish goats in two U.S. locations. J. Anim. Sci. 73:302.

Campbell, Q. P. 1984. The Development of a meat producing goat in South Africa. 2nd World Cong. Sheep Beef Cattle Breed., Pretoria, South Africa.

Casey, N. H. and W. A. Van Niekerk. 1988. The Boer goat. I. Origin, adaptability, performance testing, reproduction and milk production. Small Rumin. Res. 1:291.

Lu, C. D. and M. J. Potchoiba. 1990. Feed intake and weight gain of growing goats fed diets of various energy and protein levels. J. Anim. Sci. 68:1751.

Naude, R. T. and H. S. Hofmeyr. 1981. Meat Production. In: C. Gall (Ed.) Goat Production. p 285. Academic Press, London.

SAS. 1990. SAS/STAT User's Guide, Version 6, 4th Edition. SAS Inst. Inc., Cary, NC.

SAS. 1992. SAS Technical Report P-229. SAS/STAT Software Changes and Enhancements, Release 6.07. SAS Inst. Inc., Cary, NC

Shelton, M. 1978. Reproduction and breeding of goats. J. Dairy Sci. 61: 994.

Van Niekerk, W. A. and N. H. Casey. 1988. The Boer goat II. Growth, nutrient requirements, carcass and meat quality. Small Rumin. Res. 1:355.

Growth and Carcass Characteristics of Spanish, ¼ Boer, and ½ Boer Wethers after 66 Days on Feed

R.V. Machen, E.R. Holland, L.W. Thigpen, Jr., and K.G. White

ABSTRACT

Rate of gain and feed efficiency were measured during a 66-d feeding trial involving 150 meat goat wethers (Spanish, ¼ Boer, and ½ Boer; 50 each). Rate of gain was related to percentage Boer; mean average daily gains (lb/hd/d) for the breed groups were .25, .33, and .49 for the Spanish, ¼ Boer, and ½ Boer, respectively. Feed efficiency (lb feed/lb gain) was similar for the Boer-influenced groups (8.2 and 8.3 for ¼ Boer and ½ Boer, respectively). When compared to the Spanish wethers (10.8), Boer-influenced kids were 29% more efficient. On a live weight basis, ½ Boer wethers produced heavier carcasses with larger loineye areas. However, when compared on a per lb of carcass weight basis, carcass measurements did not differ across the three groups.

Introduction

Excitement, enthusiasm, and interest in meat goat production, marketing and consumption exploded with the introduction of the Boer goat to the United States in 1993. Developed in South Africa (Campbell, 1984) and now spread throughout the world, the Boer goat can potentially contribute several beneficial characteristics to a meat goat production system: docility, aggressive eating behavior, and rapid growth potential (Casey and Van Niekerk, 1988; Van Niekerk and Casey, 1988). Due to limited numbers of purebred animals and their relatively high value, studies to date have involved evaluation of the Boer in crossbreeding programs with Angora and Spanish does.

Relatively few studies have compared the performance of Boer-influenced and Spanish goats under feedlot conditions. In addition, studies published to date have been limited to ½ Boer influence. The objective of this study was to 1) compare the average daily gain and feed efficiency of Spanish, ¼ Boer, and ½ Boer goats under feedlot conditions and 2) to evaluate the carcass characteristics of these goats after the feeding period.

Experimental Procedure

Spring-born (7 to 8 mo old) Spanish, ¼ Boer, and ½ Boer wether kids (n = 50 per group) were selected by weight postweaning and fed in breed groups (one pen per group) for 66 d to evaluate feedlot performance and carcass characteristics. Wethers were selected such that average initial weight would be near 50 lb. The ¼ Boer (½ Boer bucks bred to Spanish does) and ½ Boer (purebred Boer bucks on Spanish does) wethers were reared from the same flock of Spanish does on one ranch. Sires used to produce the Boer-influenced kids were distantly related. The Spanish wethers were selected from another flock to match the weight of the ½ Boer wethers. All kids were castrated at approximately the same age. Sire, dam, and birth date records were not available for each kid.

Wethers were self fed a commercially available, 14% crude protein alfalfa-based pellet containing approximately 60% TDN. Wethers were fed as breed groups (i.e., Spanish in one pen, ¼ Boer in another pen, etc.). Pen size, shade availability, water, and feed trough space were identical for the three groups. A preliminary adjustment period of 10 d (October 10 to October 23, 1995) preceded initiation of the trial. Goats were held off feed and water overnight before each weighing. During the preliminary period, all goats were treated for internal parasites and vaccinated against Clostridium perfringens (types C and D) and tetanus.

Upon completion of the feeding period, five head per breed group (10%) were transported to a nearby slaughter facility for carcass data collection. The five goats nearest the average live weight for each breed group were selected for slaughter. All goats were slaughtered the same day. Hot carcass weights were obtained on the kill floor. Carcass data were collected 96 h later and included chilled carcass weight, loineye area, and kidney and pelvic fat content.

Differences in average daily gain between breed groups were analyzed using the Analysis of Variance and Duncan's Multiple Range Test procedures of SAS (1992).

Results and Discussion

Rate of Gain and Feed Efficiency

One Spanish wether died (cause undetermined). Seven Spanish wethers were removed from the study after 34 d on feed due to health problems and weight loss. The ¼ Boer kids were approximately 1 mo younger than either of the other two groups and

consequently, weighed less at the start of the feeding period (Table 1). The heaviest ¼ Boer kids available were used. Average daily gain was positively related to Boer influence (Table 1) and different among the three groups ($P < .0001$).

Whereas rate of gain is important, feed efficiency is an equally important characteristic. The previously mentioned aggressive eating behavior of the Boer is demonstrated in Table 1. As indicated, when feed consumption is expressed as a percentage of body weight, the Boer-sired kids exhibited greater feed consumption. Likewise, because they also gained at a faster rate, the Boer-sired kids converted feed to gain more efficiently (8.2, 8.3, and 10.8 for ¼ Boer, ½ Boer, and Spanish, respectively). The higher feed consumption exhibited by the ½ Boer relative to the other kids is inconsistent with the results of a previous study reported by Waldron et al., 1995. Therefore, conclusions about feed consumption differences due to breed of sire is an area that needs further research.

Table 1. Growth and performance of Spanish, ¼ Boer, and ½ Boer wethers during a 66-day feeding period

Performance measure	Spanish	¼ Boer	½ Boer
Initial weight, lb	51	40	52
Final weight, lb	69	61	84
ADG, lb/d	.25[a]	.33[b]	.49[c]
Daily feed intake (as fed), lb/hd/d	2.7	2.7	4.1
Daily feed intake, % BW	4.6	5.3	6.1
Feed:gain	10.8	8.2	8.3
Feed cost of gain[d], ¢/lb	100	76	79

[a,b,c]Different letters within a row indicate difference ($P < .01$).
[d]Feed cost - $185/ton.

Feed cost of gain is another economically important factor to consider. Facilities limited the number of feed groups to three. Because wethers were fed as breed groups, statistical analysis of the feed efficiency data was precluded. Given a feed cost of $185/ton delivered to the producer, a market value of $0.75/lb (live weight) and considering the feed conversions shown above, it appears that feed cost of gain came near breakeven (market value $0.75 to $0.80/lb live weight) for the Boer-sired wethers ($0.76 and $0.79) but was not economically feasible for the Spanish wethers ($1.00 /lb of gain). This economic analysis refers only to feed cost of gain and does not provide for a return to overhead, management, or interest.

It should also be noted that feed costs were at a 3 to 4-yr high during this trial. In addition, had the energy content of the ration been increased, feed efficiency may have been more favorable. Less expensive feed ingredients and a more efficient feed conversion could substantially improve the economic feasibility of feeding meat goats.

Carcass Characteristics

Goats were scheduled for slaughter near the end of the year. Live weight of the goats upon completion of the study (> 60 lb) precluded the slaughter of large numbers. A logistical problem involved location of a packer capable of slaughtering goats and merchandising carcasses weighing in excess of 30 lb. Therefore, slaughter numbers were restricted.

Data from this small group of goats is presented in Table 2. Due to the limited carcass data available, statistical analysis was not performed for carcass parameters. Dressing percentage was calculated using hot carcass weight and live weight at slaughter (goats were held off feed and water overnight prior to slaughter). A weekend and a holiday fell between slaughter and carcass fabrication; therefore, chilled carcass weights were recorded 96 h post-slaughter. Cooler shrink was calculated as the difference between hot and chilled carcass weights, expressed as a percentage of hot weight. Carcasses were separated between the 12th and 13th rib for fat thickness and loineye measurements. Loineye area data represent the average of two independent evaluators. Kidney and pelvic fat was removed at fabrication and includes the kidneys.

Table 2. Carcass characteristics of Spanish, ¼ Boer, and ½ Boer wethers after 66 days on feed

Carcass characteristics	Spanish	¼ Boer	½ Boer
Live wt, lb	68	61	83
Hot carcass wt, lb	35.4	31.2	42.5
Dressing percentage, %	52	51	51
Chilled carcass wt, lb	33.2	29.6	41.3
96-h cooler shrink, %	6.3	5.1	4.4
Kidney and pelvic fat[1], %	6.1	5.5	5.3
Loineye area, in.[2]	1.62	1.57	2.25
Loineye area/lb carcass, in.[2]	.05	.05	.05

[1]Includes the kidneys.

Results of this study concur with those of the Waldron et al., 1995. Boer-sired kids grew faster and produced more marketable product when compared to Spanish at a constant age. However, when compared on a constant carcass weight basis, differences among breed groups were near zero. All carcasses were essentially devoid of subcutaneous fat over the loineye at the 12th rib; therefore, fat thickness was not recorded. However, a significant portion of the carcass weight, up to 6%, was internal fat.

Although the 96-h interval between slaughter and fabrication is not typical for most packers, it does point

to a handling difference between goat and lamb, beef, or pork carcasses. Unlike the other species, the goat has very little subcutaneous fat and has little or no protection from desiccation. Therefore, if goat meat is to be shipped significant distances, it must be protected from dehydration (i.e., fabricated into wholesale cuts and vacuum packaged).

Several experimental design obstacles beyond the authors' control should be mentioned. These include:

1) The Spanish wethers used were from a different ranch and thereby came from a different genetic pool than the Boer-influenced kids. Therefore, maternal influence may have influenced the postweaning performance of the wethers. Visually, the quality (size and conformation) of the does from the two ranches did not differ.

2) Health problems encountered in the Spanish wethers may have been due to a change in environment. After the initial removal of obviously sick animals, the Spanish wethers completing the project exhibited no sign of illness. Postmortem examination of the five Spanish wethers slaughtered provided no indication of health problems.

3) The ¼ Boer wethers were approximately 1 mo younger than either of the other two breed groups. This age difference could have influenced the results. Ideally, age would be used as a covariate in the data analysis, but, as indicated, birth dates were not available. Across the industry, few meat goat producers keep individual birth records.

4) The limited facilities did not allow pen replication of the breed groups. Statistical treatment of live weight gain was based on growth of individual animals.

Implications

What impact the Boer goat will have on the meat goat industry will ultimately be a function of its ability to produce a profit. The postweaning data from this and other studies demonstrate that, when nutrition is not a limiting factor, the Boer-sired kids did gain faster.

Perhaps the greatest benefit of using Boer sires, relative to Spanish, is increased growth potential of the Boer-cross kids. The carcass data from this and other studies suggest that there are little or no compositional differences attributable to breed of sire when goats of similar live weight or similar carcass weight are compared.

Growth and carcass evaluation studies to date have been confined to kids with ½ Boer influence or less. Subsequent studies involving larger percentages and purebreds will further quantitate the contribution of the Boer to the U.S. meat goat industry.

Acknowledgment

The authors are grateful to Ferrell Davis and Bob Duke, 4D Ranch, Utopia and Rodney Robinson, Rancho Pegaso, Kerrville for furnishing the goats and providing feed to make this project possible.

Literature Cited

Campbell, Q.P. 1984. The development of a meat producing goat in South Africa. Second World Congr. Sheep and Beef Cattle Breed., Pretoria, South Africa.

Casey, N.H., and W.A. Van Niekerk. 1988. The Boer Goat. I. Adaptability, performance testing, reproduction and milk production. Small Rumin. Res. 1:291.

SAS. 1992. SAS User's Guide: Statistics (Version 6.03). SAS Inst., Inc. Cary, NC.

Van Niekerk, W.A., and N.H. Casey. 1988. The Boer Goat II. Growth, nutrient requirements, carcass and meat quality. Small Rumin. Res. 1:355.

Waldron, D.F., J.E. Huston, P. Thompson, T.D. Willingham, J.S. Oman, and J.W. Savell. 1995. Growth rate, feed consumption and carcass measurements of Spanish and Boer x Spanish goats. J. Anim. Sci. 73, Suppl. 1:253.

A Comparison of Angora and Spanish Does for Producing Crossbred Goats for Slaughter: Effects on Growth Rate and Feed Efficiency

D.F. Waldron, T.D. Willingham, and P.V. Thompson

ABSTRACT

Growth and feed efficiency were evaluated in kids born to Angora and Spanish does that had been bred to either Boer, Spanish or Angora bucks. The data analyzed included 418 records on birth weight, 375 records on 100-d weight, and 80 records on postweaning gain and weight. Boer- or Spanish-sired kids born to Angora dams were .29 lb lighter ($P > .01$) at birth and not significantly different for weight at 100 d of age, weight at 8 mo of age, postweaning gain, and feed:gain ratio when compared to kids born to Spanish dams. The purebred Angora kids were compared to kids from Angora does and meat breed bucks. At 100 d of age, the purebred Angora kids weighed 6.3 lb less than kids sired by meat breed bucks. Feed:gain ratio of purebred Angora kids was less desirable ($P < .07$) than Angora-cross kids sired by meat breed bucks (11.2 vs 8.2).

Introduction

The loss of the mohair incentive program (Jones and Wyse, 1994), the relative stability of the price of goat kids for slaughter, and the potential high growth rates of Boer goats (Casey and Van Niekerk, 1988) have caused some mohair producers to consider breeding their Angora does to meat goat sires. The practice of breeding Angora does to meat goat sires allows a mohair producer to continue shearing adult females and produce a crossbred kid which will be more desirable to buyers of slaughter goats. However, the loss of income from hair production on the kid crop must be considered. An alternative system would be raising kids for slaughter from Spanish does bred to meat goat sires. The relative profitability of breeding Angora does to meat goat sires or to Angora sires will be a function of the price of mohair, the difference in growth rate between Angora and Angora-cross kids and the difference in value of the kids sold. A comparison of using Angora does vs using Spanish does requires estimates of differences in reproduction, growth rate, and value of kids at the time of sale. The objectives of this study were to 1) estimate growth rate and feed efficiency differences between kids born to Angora or Spanish dams when bred to either Angora, Spanish, or Boer bucks and 2) estimate growth rate and feed efficiency differences between purebred Angora kids and Angora-cross kids.

Materials and Methods

A herd of Spanish and Angora does was used to produce Boer x Spanish (BS), Boer x Angora (BA), Spanish x Spanish (SS) , Spanish x Angora (SA) and Angora x Angora (AA) kids in March and April of 1995. The does were assigned at random within breed to be bred to either Boer, Spanish, or Angora bucks. The same Spanish ($n = 4$) and Boer bucks ($n = 9$) were mated to both Angora and Spanish does. Because of the limited number of Boer bucks and their associated high cost, frozen thawed semen was used to produce most of the BS and BA kids, while Spanish bucks were naturally mated in single sire pastures and Angora bucks were group mated with the Angora does. The number of does kidding and number of kids with records are shown in Table 1 by breed of sire and breed of dam.

The does were maintained and all kids were born at the Winters Ranch, near Brady, Texas. The kids were paired with their dams and weighed within 24 h of birth. All male kids from Angora dams and a random sample of the male kids from Spanish dams were castrated at an average age of 87 d. All kids and does were maintained on pasture until approximately 100 d of age. Kids were weaned from their dams at approximately 100 d of age.

At weaning, male kids were assigned randomly within breed of sire-breed of dam to pens in a feedlot for the postweaning growth period, starting at approximately 4 mo of age. There were three pens each of BA, SA, BS and SS and two pens of AA. An adjustment period of approximately 4 wk was used to get the kids on feed before starting the trial. The kids were fed an 80% concentrate, 14% crude protein diet. The postweaning growth period was 100 d. Feed intake was recorded for each pen. Feed consumed was expressed as a percentage of the average live weight of the kids in the pen. A feed:gain ratio was computed by dividing feed consumed by weight gain per pen.

Statistical Analyses

Weight data were analyzed with PROC MIXED (SAS, 1992). The model included fixed effects for breed of sire x breed of dam interaction, sex, and type of birth, a random effect for sire within breed and a covariate for date of birth for birth weight, or age at weaning (for 100 d wt). Postweaning traits were analyzed with a model that included fixed effects for

Table 1. Number of kids (number of does) with records by breed of sire and breed of dam

	Birth weight records Breed of dam		100 d wt Breed of dam		Postweaning wt Breed of dam	
Breed of sire	Ang.	Span.	Ang.	Span.	Ang.	Span.
Angora	22(21)		20		7	
Boer	59(46)	152 (88)	51	134	20	19
Spanish	21(18)	174(112)	20	158	15	19

breed of sire x breed of dam interaction and type of birth, random effects for pen and sire within breed and a covariate for age at the start of the trial. Feed consumption and feed:gain ratio were analyzed on a pen basis. The model that was used included a fixed effect for breed of sire x breed of dam interaction. The feed consumption and feed:gain ratio data were analyzed with PROC GLM (SAS, 1990).

Results

The results of the birth weight analysis in Table 2 show that kids from Spanish dams were .29 lb larger at birth. The probability (P) values of comparisons of Angora vs Spanish are underestimated because independence across does was assumed and there were relationships among the does. However, no pedigree records were available for these does. At 100 d of age, kids from Angora dams were not significantly heavier than kids from Spanish dams. The postweaning data shown in Table 2 indicate that kids from Angora and Spanish dams had similar live weights at 8 mo of age and similar postweaning average daily gain (ADG).

The results shown in Table 3 were calculated from the estimates of kids from Angora dams. The estimated differences in performance of purebred Angora kids compared to Angora-cross kids show that the Angora kids were lighter and had a lower growth rate than Angora-cross kids. However, the small number of Angora kids available for the postweaning trial resulted large standard errors, and therefore, the estimated differences were not significantly different from zero.

Table 2. Least squares means ± (SE) of breed of dam for weights and gains

Trait	Angora	Spanish	Angora - Spanish	P
Birth wt, lb	6.20 ± .11	6.50 ± .07	-.29 ± .11	.01
100 d wt, lb	36.6 ± 1.07	35.9 ± .56	+.7 ± 1.13	.53
8 mo wt, lb	57.7 ± 3.33	56.1 ± 3.04	+ 1.6 ± 4.1	.69
postweaning ADG, lb	.184 ± .026	.181 ± .024	+ .003 ± .032	.93

There were no significant differences between kids from Angora and Spanish dams for feed consumption or feed:gain ratio (Table 4). Kids from each of the breeds of sire had similar feed consumption expressed as a percentage of body weight (Table 5). However, the feed:gain ratio of the Angora-sired kids was lower (P = .06) than that of the kids sired by meat breeds.

Discussion

The number of kids born to Angora dams was lower than desired. Because of the low number of AA and SA kids, this trial should be repeated before conclusions should be drawn. The extremely high standard errors of the estimates that include the AA kids indicate that the results may differ if this experiment were to be repeated. Therefore, the results should be viewed with caution.

The data from this study suggest that the growth rate of kids sired by meat breed bucks from Angora dams is similar to or slightly greater than that of kids from Spanish dams. If the objective is to produce goat kids for slaughter, the Angora doe can be used to produce kids that grow at least as fast as kids produced by Spanish does. However, the lower reproductive rate of Angora does relative to Spanish does (Thompson and Shelton, 1982) suggests income from slaughter kid production will be less with Angora does. However, mohair sales income from the Angora does may offset the disadvantage in reproductive rate.

Table 3. Least squares means ± (SE) of breed of sire for weights and gains

Trait	Angora	Boer	Spanish	Angora - Meat sires	P
Birth weight, lb	5.81 ± .25	6.44 ± .12	5.96 ± .20	-.39 ± .27	.15
100 d weight, lb	30.3 ± 1.91	38.6 ± 1.11	34.5 ± 1.81	-6.3 ± 2.1	.01
8 mo wt, lb	36.4 ± 524.33	63.7 ± 4.06	51.6 ± 5.44	-21.3 ± 524.33	.97
postweaning ADG, lb	.087 ± 2.122	.198 ± .032	.170 ± .042	-.097 ± 2.122	.96

Table 4. Feed consumption and efficiency by breed of dam

Trait	Angora	Spanish	Angora - Spanish	P
Feed consumption, % of live weight/d	3.02 ± .09	3.02 ± .09	.00 ± .12	.98
Feed:gain ratio	8.2 ± .71	8.6 ± .71	.40 ± 1.0	.70

Table 5. Feed consumption and efficiency by breed of sire

Trait	Angora	Boer	Spanish	Angora - Meat sires	P
Feed consumption, % of live weight/d	3.01 ± .15	2.97 ± .12	3.07 ± .12	-.01 ± .18	.97
Feed:gain	11.2 ± 1.23	8.4 ± 1.01	8.0 ± 1.01	-3.0 ± 1.42	.06

In this study, which did not include enough Angora sires to draw general conclusions, the growth rate of crossbred kids from Angora dams was greater than purebred Angora kids. The weight difference between Angora-cross kids and Angora kids at 100 d of age or later suggests that the income from selling kids to slaughter will be substantially greater when they are sired by either Boer or Spanish sires as compared to Angora sires. This extra value from selling heavier kids must be compared with the loss of income due to mohair production from the purebred Angora kids.

This study has provided data on the relative growth rates of Angora and Angora-cross kids. A thorough analysis of the relative profitability of breeding Angora does to either Angora bucks or meat breed bucks is required in order to make recommendations on breeding plans. A possible plan would be to use Angora bucks at the beginning of the breeding season and meat breed bucks subsequently. In this program the mohair clip from the kids would be more uniform because of the narrow range of birthdates of the purebred Angora kids. This program would also be expected to result in a more uniform kid crop because the later born Angora-cross kids would have a higher growth rate than the Angora kids.

Implications

The growth rate and feed:gain ratio of Angora-cross kids are similar to that of Spanish and Spanish-cross kids. Therefore, the Angora doe can be used to produce crossbred kids for slaughter that will not be at a weight disadvantage to kids from Spanish does.

Acknowledgments

This project was supported in part by gifts of Boer semen from Landcorp Farming (Canada) Limited, Don Smith and T4 Ranch (W.E. Whitehead). Their support of our research program is greatly appreciated.

Literature Cited

Casey, N.H. and W.A. Van Niekerk. 1988. The Boer goat. I. Origin, adaptability, performance testing, reproduction and milk production. Small Rumin. Res. 1: 291.

Jones, L.L. and A.J. Wyse. 1994. The economic impact of the curtailment of incentive payments to the wool and mohair industry of Texas. Texas Agric. Exp. Sta. Prog. Rep. CPR 5212.

SAS. 1990. SAS/STAT User's Guide, Version 6, 4th Edition. SAS Inst. Inc., Cary, NC, USA.

SAS. 1992. SAS Technical Report P-229. SAS/STAT Software Changes and Enhancements, Release 6.07. SAS Institute Inc., Cary, NC.

Thompson, P. and M. Shelton. 1982. Preliminary observations on results of crossing Angora and meat-type (Spanish) goats. Texas Agric. Exp. Sta. Prog. Rep. CPR 4026.

Effects of Protein Level and Roughage Level in Feedlot Rations for Goats

J.E. Huston and D.F. Waldron

ABSTRACT

Two studies were conducted to determine the effects of ration characteristics on the performance of kid goats in the feedlot. Growth rates were similar and not statistically different in kids fed 14 and 16.4% protein rations. However, goats in these studies did not record high gains, and additional studies are needed to determine the possible relationship between live weight gain potential and protein content of the ration. Live weight gain and feed efficiency of kid goats reflected similar effects of two different roughage levels to those observed with lambs and feedlot cattle. It is suggested that a lower roughage feedlot ration will result in lower consumption, similar gain, and improved feed efficiency.

Introduction

The apparent high demand for goat meat suggests that the goat industry is on the brink of substantial expansion. Historically, goats entering the meat trade have been either young kids (20 to 40 lb) for outdoor barbecues or adult salvage animals for processed meat products. With the development of a marketing system for meat goats, a demand is anticipated for a goat feedlot industry to provide uniform carcasses for wholesale and retail cuts. Relatively little information is available on feedlot performance of goats or on ration characteristics. Studies were conducted to compare growth rates of goats fed rations containing two levels of protein (Exp. 1) and two levels of roughage (Exp. 2).

Materials and Methods

Experiment 1

Male Angora, Spanish, and Boer cross (Spanish x Boer) goats were assigned to rations containing either 14 or 16.4% protein (Table 1) and fed for 112 d during the summer and fall of 1994. Two pens of 9 to 12 kids per pen were fed for each breed or breed cross at each protein level. The rations were fed daily in open troughs to allow free choice consumption, and refusals were weighed back as needed (not less frequent than 4-d intervals). The goats were weighed at the beginning of the study and at 28-d intervals thereafter. Initial and final weights were used to calculate daily gain. Data from some kids were not included in the final analysis because of the obvious adverse effects of social ordering within the pens. Breed comparisons are being reported separately, and in this report, only the effects of protein level and breed x protein level on live weight gain were tested (SAS, 1991).

Experiment 2

Male intact Angora and crossbred (Spanish x Boer) castrate kids were assigned to two rations (Table 1)

Table 1. Ingredients and estimated nutrient contents of rations fed in experiments to determine effects of protein level (Exp. 1) and roughage level (Exp. 2) on performance of kid goats in the feedlot

	Experiment 1 Protein level		Experiment 2 Roughage level	
Item	Medium	High	Moderate	Low
Ingredients, %				
Cottonseed hulls	12	12	12.5	
Alfalfa	5	5	12.5	12.5
Sorghum grain	68	60.2	61.5	76
Cottonseed meal	4	8	3	2
Soybean meal	4	8	3	2
Fish meal			1	1
Molasses	4	4	4	4
Ammonium chloride	.5	.5	.5	.5
Mono-dicalcium phosphate	.6	.4		
Calcium carbonate	1.4	1.4	1	1
Urea			.5	.5
Vitamin/mineral premix[1]	.5	.5	.5	.5
Rumensin[2]				
	100.0	100.0	100.0	100.0
Estimated nutrient content				
Crude protein	14.0	16.4	15.0	15.2
TDN	68.4	68.0	67.0	72.1

[1]Contained amounts of vitamins A, D, and E; salt; and trace minerals to satisfy minimal requirements.
[2]Rumensin added to monensin at 10 mg/lb feed.

having different levels of roughage for a 78-d feeding period. Two pens of either five or six kids per pen were fed for each breed or breed cross for each ration. The goats were fed daily for free choice consumption, and refusals were weighed back at 2- to 4-d intervals and discarded. Because the experiment was confounded for breed and sex (Angora bucks and crossbred wethers), the data were analyzed as a randomized block design (SAS, 1991) with breed (sex) representing blocks for evaluating effects of treatment (roughage level). Data included daily live weight gain, daily feed intake, and feed conversion (FC; lb feed/lb gain).

Results and Discussion

The goats in Exp. 1 gained .31 and .33 lb/d at the medium and high protein levels, respectively (Table 2).

Table 2. Effect of ration protein level on growth rate of male kid goats (Exp. 1)

	Protein level			
Item	Medium	High	Change, %	P[1]
Number of kids	59	60		
Average live weight, lb				
Initial	43.0	41.7		
Final	77.5	78.2		
Gain	34.5	36.5		
Live weight gain, lb/d	.31	.33	+6	.51

[1]Probability that difference is due to chance.

Because the data showed no significant (P = .72) interaction for breed x protein level, the data were pooled for analysis of the effect of protein level. This 6% higher gain for goats receiving the high protein ration was not significantly different (P = .51). In studies with Angora kids including a recent study (Huston et al., 1996), gain increased with increases in protein content to above 16% of the ration. Also, a study with Spanish kids in the feedlot suggested that gain increased with increases in protein level up to 17% (Shelton and Thompson, 1976). However, in that experiment the protein concentrates contained up to 6% feather meal which may not have been utilized well. The data in the present study indicate that for the general population of meat goat kids weighing from 40 to 80 lb and fed relatively high concentrate rations, 14% protein is likely adequate. Because there is presently such a wide variation in the meat goat population, additional studies with high-performance individuals are needed to determine whether there is a relationship between growth potential and ration protein requirements.

Results of Exp. 2 (Table 3) are consistent with those generally observed for lambs and growing cattle fed in confinement. In cattle and sheep experiments, as roughage level in feedlot rations decreased from a maximal intake level, feed intake decreased and live weight gain either was not affected or was slightly depressed. The net effect was that feed conversion improved (less feed required for each unit of gain).

Table 3. Live weight gain, feed intake, and feed efficiency of male kid goats fed rations containing two levels of roughage (Exp. 2)

	Roughage level			
Item	Moderate	Low	Change, %	P[1]
Number of kids	21	20		
Live weight gain, lb/d	.27	.24	-8	.68
Feed intake, lb/d	2.25	1.85	-18	.14
Feed conversion, lb feed/lb gain	8.3	7.7	+8	.55

[1]Probability that difference is due to chance.

Although these data are consistent with results for sheep and cattle studies, none of the differences between treatments were statistically significant. Variability in the performance of individual goats in the feedlot makes these kinds of studies more difficult to interpret. However, it appears that goats respond similarly to sheep and cattle to roughage level in feedlot rations.

Literature Cited

Huston, J.E., K.W. Bales, and C.J. Lupton. 1996. Effects of ration protein level on live weight gain and mohair growth and characteristics in Angora billy kids. Texas Agric. Exp. Sta. Consol. Prog. Rep. CPR-5257.

Shelton, M., and P.V. Thompson. 1976. Influence of protein level and monensin on performance of male kid goats fed in drylot. Texas Agric. Exp. Sta. Prog. Rep. PR-3395.

SAS. 1991. SAS systems for linear models. SAS Inst. Inc. Cary, N.C.

Effects of Ration Protein Level on Live Weight Gain and Mohair Growth and Quality in Male Angora Kid Goats

J.E. Huston, K.W. Bales, and C.J. Lupton

ABSTRACT

This study was conducted to investigate the effects of level of dietary protein and of ruminally undegraded protein on live weight gain and mohair of Angora kid goats fed for slaughter. The study was designed particularly to test the effects of dietary protein level and quality on the production and characteristics of mohair that could be salvaged from Angora kid goats before slaughter. Increasing dietary protein from 10.8 to 16.4% increased live weight gain, clean fleece weight, and fiber diameter 31, 37, and 7%, respectively. Staple length and percentages of med and kemp fibers were not affected. Increasing ruminally undegraded protein in the diet did not further stimulate any responses. These data suggest that increasing the protein content of diets from below 12% up to 16% for Angora kid goats in the feedlot will have a large positive effect on mohair growth that will more than offset a slightly negative effect on mohair quality.

Introduction

Products of the various types of goats include milk, meat, fiber, and skins. Three developments during the 1990s have intensified an interest in the meat goat. (1) There is an existing and growing population in the United States who will buy and often prefers goat meat. (2) The Wool Act was rescinded, thereby phasing out the incentive payment that provided stability for the highly volatile mohair market. (3) Boer goat genetics were imported into the United States. However, historical trends indicate that mohair will once again be of high value, and a liquidation of the Angora flock may not be advisable in the long term. Some producers are considering whether to retain the Angora as a dual-purpose goat. Angora kids can be sheared once or twice then sold for meat. However, to produce an acceptable carcass, the Angora kid may require a period of feeding. A previous study (Huston et al., 1992) showed that feeding a high protein feed to replacement female kids on pasture increased the fiber diameter of mohair and perhaps decreased its value. Because the mohair is of peak value during this period (Hunter, 1993), an important question is whether feeding to produce a marketable carcass will adversely affect the value of the fleece. A study was conducted to determine the effects of the protein level and additional ruminally undegraded protein in diets of goats in the feedlot on live weight gain and mohair growth and quality.

Materials and Methods

Male Angora kid goats weaned at 4 mo and weighing 40 ± 3 lb were fed diets (Table 1) containing 10.8, 14.0, and 16.4% protein and a fourth diet containing 16.2% protein (including elevated ruminally undegraded protein; UDP). Eight groups of nine kids per group were fed with two pens of goats fed each experimental diet for 112 d. The rations were formulated to be equal in energy, calcium, and phosphorous contents. The goats were fed daily in open troughs, and refusals were weighed back every 2 to 4 d and discarded. Data from individual goats that were abused by other kids in the group and could not compete successfully were not included in the data analysis.

Table 1. Rations fed in a study to determine the effects of protein level on male Angora kid goats in a feedlot

	Protein level, %			
Ingredients, %	10.8	14.0	16.4	16.2[1]
Cottonseed hulls	12	12	12	12
Dehydrated alfalfa	5	5	5	5
Sorghum grain	75.9	68	60.2	64
Cottonseed meal		4	8	4
Soybean meal		4	8	4
Fish meal				5
Molasses	4	4	4	4
Ammonium chloride	.5	.5	.5	.5
Mono-dicalcium phosphate	.8	.6	.4	
Calcium carbonate	1.3	1.4	1.4	1
Vitamin/mineral premix[2]	.5	.5	.5	.5
Rumensin[3]	+	+	+	+
	100.0	100.0	100.0	100.0

[1]Ration contained an elevated concentration of ruminally undegraded protein (UDP).
[2]Provided vitamins A, D, and E and most trace minerals to satisfy requirements.
[3]Included at 20 g monensin/ton.

The goats were shorn, weighed, and assigned to treatment in mid July and were weighed at 28-d intervals. Initial and final weights were used to calculate average daily live weight gain (ADG) for the 112-d feeding period. At termination, the kids were weighed and shorn then held for slaughter in concert with a companion study. The fleeces were bagged separately and transported to the Texas Agricultural Experiment Station's Wool and Mohair Research Laboratory for determining clean fleece weight (CFW), fiber diameter (FD), staple length (SL), med fibers (MED), and kemp fibers (KEMP).

The data were analyzed using the general linear model (GLM) and regression (REG) procedures of the Statistical Analysis System (SAS, 1991).

Results and Discussion

The data (Table 2) showed strong linear responses in ADG and CFW (r^2 = .80 and .29, respectively) to increasing protein in the diet. Also, FD was increased at the very high levels of protein (16.4 and 16.2%). These data are consistent with studies by Huston and Shelton (1967) and Stewart et al. (1971) that showed increased live weight gain, clean fleece production, and fiber diameter with increasing protein in the diet. However, the observed increase in fiber diameter was minor compared to the increase in quantity, and the mohair was still considered to be of high value on a unitary basis. Staple length was not affected by increasing protein. This is consistent with many previous reports which suggest that staple length is not as sensitive as fiber diameter to dietary protein. Neither MED nor KEMP were affected by ration protein level.

The elevated ruminally undegraded protein did not influence any response criteria in comparison to the other high protein treatment. Although feed intake is not included in this report, the UDP treatment ration was not consumed at the same level as was the other high protein treatment, a fact that may have influenced the outcome of the comparison. Results of other studies, though inconsistent, suggest that elevated UDP can stimulate growth and mohair production in growing Angora kid goats. However, because goats are very particular about what and how much they eat, foul smells and tastes that often accompany good sources of UDP can have a greater negative effect than the potential positive effect of greater protein absorption.

Literature Cited

Hunter, L. 1993. "Mohair: A review of its properties, processing and applications" (CSIR Division of Textile Technology: Port Elizabeth, South Africa).

Huston, J.E., and M. Shelton. 1967. The influence of level of protein on performance of billy kids fed in drylot. Texas Agric. Exp. Sta. Prog. Rep. PR-2454.

Huston, J.E., C.A. Taylor, C.J. Lupton, and T.D. Brooks. 1992. Supplemental feeding of Angora female kids on rangeland. Texas Agric. Exp. Sta. Prog. Rep. PR-4940.

SAS. 1991. SAS Systems for Linear Models. SAS Inst. Inc., Cary, NC.

Stewart, J.R., M. Shelton, and H.G. Haby. 1971. Nutritional investigations with Angora goats. Texas Agric. Exp. Sta. Prog. Rep. PR-2933.

Table 2. Effects of ration protein level on live weight gain and mohair growth and characteristics of male Angora kids

	Protein level, %					
Item	10.8	14.0	16.4	16.2[1]	SEM[2]	r-square[3]
Number of kids	11	17	16	17		
Live weight, kg						
Initial	44.3	40.3	39.6	38.5		
Final	66.5	65.4	68.7	68.5		
ADG, lb/d	.20	.22	.26	.27	.02	.80
CFW, g/d	9.1	10.7	12.5	12.3	.92	.29
FD, μm	27.2	27.6	29.1	29.6	.93	.14
SL, in.	4.0	4.1	4.1	4.2	.13	.08
MED, %	.81	.75	.76	.80	.17	.01
KEMP, %	.24	.28	.28	.41	.09	.01

[1]Ration contained an elevated concentration of ruminally undegraded protein (UDP).
[2]Standard error of the mean.
[3]Fraction of the variation attributable to regression.

Intake of Forages of Different Digestibility by Dry, Pregnant, and Lactating Ewes

J.E. Huston, K.W. Bales, and B.S. Engdahl

ABSTRACT

A study was conducted to determine the voluntary intake of forages of different digestibility by ewes that were either fat or thin and either dry, pregnant, or lactating. When body weight was adjusted to a common condition score, voluntary intake in g/kg live weight was not affected by body condition. Forage consumption by ewes in different physiological states was in the order of dry, nonpregnant > pregnant < lactation. Within the range of the forages used in this study, dry matter intake decreased as forage digestibility increased, but intake of digestible dry matter did not change. These data suggest that intake of forages in the upper range of digestibility is determined by a physiological target for digestible dry matter (energy).

Introduction

Forage consumption is the most important voluntary activity of grazing animals and is the basis of animal production from rangeland. The level of productivity of animals is limited by 1) their genetic potential to be productive and 2) the level of nutrients (protein, energy, etc.) consumed. A previous report described an attempt to estimate supplemental feed needs for range ewes (Huston, 1986). In order to improve estimates of forage intake, an experiment was conducted to determine the effects of forage digestibility on intake in ewes that were either fat or thin and either dry (D), pregnant (P), or lactating (L).

Materials and Methods

A feeding experiment was conducted in early February, 1994 to determine the voluntary intake of three forages by ewes. The ewes were prepared during the summer and fall of 1993 for the feeding experiment. Half of the ewes were nutritionally favored (given better pasture and supplemental feed) and half were disfavored (given poorer pasture and no supplemental feed) to create ewes that were fat and thin (body condition scores, > 4.0 and < 2.5, respectively). Synchronized breeding was attempted using two prostaglandin injections (Lutalyse® at 5 mg, ten d apart) before introducing a fertile ram and observing breeding marks. The plan was to have 15 ewes in each body condition, in each physiological state (Table 1). Early-cut and late-cut alfalfa hays and a super-high quality ryegrass hay each would be fed to five of the 15 ewes. The two alfalfa hays represented early season and late season cuttings from the same farm in Deming, New Mexico. The ryegrass was obtained from a midwinter cutting from a farm near Uvalde, Texas.

The trial to determine voluntary intake was initiated when lambs nursing the lactating ewes were at least 1 wk old and the pregnant ewes were within 3 wk of parturition. The sheep were fed ground alfalfa hay as a group for 5 d. Then ewes were penned either individually or as a ewe-lamb pair and fed a high-quality alfalfa hay for 5 d. The test forages were fed for 4 d to establish voluntary intake (refusals discarded each day), then offerings and refusals were measured for 4 d. Lambs were prevented from consuming the forages offered to the ewes but were offered a small amount of forage that was inaccessible to the ewes.

Digestibilities of the three forages were determined in a conventional digestion trial with three ewes fed each forage in stalls allowing total collection of feces. The trial included a 10-d preliminary adjustment period followed by a 4-d collection period. The forages were offered free choice.

The data were analyzed using GLM (SAS, 1991) to calculate least squares means and standard errors. The model included effects for physiological state (D, P, L), body condition (thin, fat), and forage (Alfalfa1, Alfalfa3, Ryegrass) and two-way interactions of the main effects. PROC REG was used to determine the relationship between forage digestibility and voluntary intake.

Results and Discussion

The actual numbers of ewes in the different treatment groups differed from planned (Table 1) because several ewes failed to breed as planned. As a result, the "pregnant" physiological state was not included in the analyses when all three forages were considered. Likewise, the "ryegrass" forage was not included when all three physiological states were considered.

The digestibility values of the forages (Table 2) differed from the expected. The late-cut alfalfa (Alfalfa3), expected to be about 55% digestible, was higher in digestibility than the early-cut hay (Alfalfa1) (66.3 vs 60.8%, respectively). The ryegrass (Ryegrass) was expected to have a digestibility in the range of 72 to 75%. The lower value (66.7%) may have resulted from drying difficulties during the cool, humid January days. The net result was that the range in digestibility of the forages was more narrow than desired.

Table 1. Assignment of ewes to treatments in a study of the effects of physiological state, body condition, and forage digestibility on intake of dry matter and digestible dry matter in Rambouillet ewes

Physiological state	Body condition	Forage	Number of ewes: Planned	Number of ewes: Actual
Dry, nonpregnant	Thin	Alfalfa1	5	10
		Alfalfa3	5	9
		Ryegrass	5	4
	Fat	Alfalfa1	5	6
		Alfalfa3	5	6
		Ryegrass	5	5
Pregnant	Thin	Alfalfa1	5	2
		Alfalfa3	5	4
		Ryegrass	5	0
	Fat	Alfalfa1	5	5
		Alfalfa3	5	5
		Ryegrass	5	1
Lactating	Thin	Alfalfa1	5	5
		Alfalfa3	5	4
		Ryegrass	5	4
	Fat	Alfalfa1	5	5
		Alfalfa3	5	5
		Ryegrass	5	5
		Total	90	87

Table 2. Dry matter content and digestibility of forages in a study of the effects of physiological state, body condition, and forage digestibility on intake of dry matter and digestible dry matter in Rambouillet ewes

Forage	Forage contents: Dry matter, %	Forage contents: Dry matter digestibility, %
Alfalfa1	88.8	60.8
Alfalfa3	88.4	66.3
Ryegrass	87.9	66.7

Interactions among the main effects (physiological state, body condition, and forage) were not statistically significant. Therefore, only the main effects will be presented and discussed.

Physiological state affected live weight, body condition score, and forage intake (Table 3). Live body weights were highest for pregnant ewes and lowest for lactating ewes. Dry ewes were intermediate in live weight, but when corrected to a constant body condition score of 3.0, live weights were similar for dry and lactating ewes and about 15 lb (approximate weight of conceptus) lower than for pregnant ewes. Lactating ewes lost body condition rapidly following lambing, and those in the "fat" group had body condition scores lower than the targeted 4.0 value. Forage intake was highest for lactating ewes and lowest for pregnant ewes irrespective of the method of expression. On an adjusted live weight basis, pregnant and lactating ewes consumed 83 and 122%, respectively, of the amount consumed by the dry ewes. Assuming that all ewes were identical in body size when in the same body condition and physiological state, the relative voluntary intakes were 1.0, .88, and 1.17 for ewes that were dry, pregnant, and lactating, respectively.

Fat ewes weighed more than thin ewes (Table 4), but the difference in body condition score was less than planned. Adjusted live weights were similar for the two groups. Although both dry matter and digestible dry matter intakes were higher in thin ewes when expressed on a live weight basis, intake per unit of adjusted live weight did not differ. That is, actual voluntary intake was not affected by body condition in this study.

Table 3. Live body weights, body condition scores, and voluntary forage intakes of ewes that were either dry, pregnant, or lactating

Item	Physiological state: Dry	Physiological state: Pregnant	Physiological state: Lactating	SEM[3]
Ewes, No.	31	16	19	
Live weight, lb	151	170	133	4.2
Body condition score[1]	3.6	3.8	2.1	.14
Adjusted live weight, lb[2]	147	161	142	1.6
Dry matter intake				
lb/d	4.2	3.7	4.9	.18
g/kg LW	27.7	22.3	37.0	1.21
g/kg adjusted LW	28.1	23.3	34.3	1.18
Digestible dry matter intake				
lb/d	2.6	2.4	3.1	.11
g/kg LW	17.6	14.2	23.3	.74
g/kg adjusted LW	17.8	14.8	21.7	.72

[1]Body condition scores were assigned by a four-member panel on a five-point scale (1 = very thin; 5 = very fat).
[2]Live weight was adjusted to a standard body condition of 3.0 using a regression of body condition score (X_1) and height (X_2) on body weight (Y).
[3]Standard error of the mean.

The influence of forage on voluntary intake by ewes (Table 5) suggested an effect of energy density (forage digestibility). Whereas dry matter intake seemed to decrease as forage digestibility increased, digestible dry matter intake was rather constant across all forages. This is illustrated in Figure 1 which shows the overall regressions (pooled data) for forage digestibility on dry matter and digestible dry matter intake by all ewes. These data suggest that the ewes voluntarily consumed forage until a threshold requirement for digestible dry matter was reached. This threshold was different for ewes in the different physiological states, but in each case, the lower digestible forage (Alfalfa1; 60.8 DDM)

Table 4. Live body weights, body condition scores, and voluntary forage intakes of ewes that were either "thin" or "fat"

	Body Condition		
Item	Thin	Fat	SEM[3]
Ewes, No.	36	32	
Live weight, lb	134	154	3.20
Body condition score[1]	2.6	3.5	.15
Adjusted live weight, lb[2]	145	144	1.27
Dry matter intake			
lb/d	4.3	4.3	.17
g/kg LW	32.2	28.5	1.30
g/kg adjusted LW	29.5	29.8	1.19
Digestible dry matter intake			
lb/d	2.7	2.8	.10
g/kg LW	20.6	18.3	.81
g/kg adjusted LW	18.9	19.2	.74

[1]Body condition scores were assigned by a four-member panel on a five-point scale (1 = very thin; 5 = very fat).
[2]Live weight was adjusted to a standard body condition of 3.0 using a regression of body condition score (X_1) and height (X_2) on body weight (Y).
[3]Standard error of the mean.

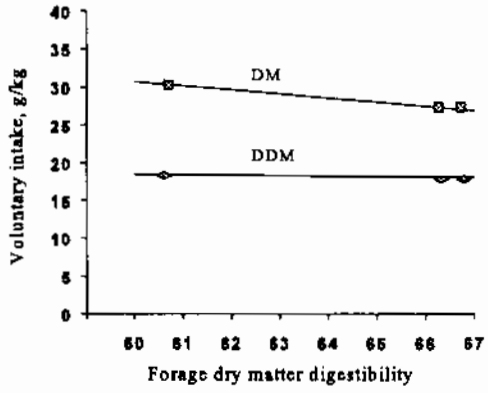
Table 5. Live body weights and body condition scores of ewes and their voluntary intakes of three forages

	Forage			
Item	Alfalfa1	Alfalfa3	Ryegrass	SEM[3]
Ewes, No.	26	24	18	
Live weight, lb	143	145	142	4.5
Body condition score[1]	3.0	3.0	2.9	.21
Adjusted live weight, lb[2]	144	147	144	1.5
Dry matter intake				
lb/d	4.6	4.3	3.9	.20
g/kg LW	32.4	29.9	28.3	1.61
g/kg adjusted LW	31.8	29.0	27.5	1.41
Digestible dry matter intake				
lb/d	2.8	2.8	2.6	.13
g/kg LW	19.7	19.8	18.8	1.03
g/kg adjusted LW	19.3	19.3	18.3	.91

[1]Body condition scores were assigned by a four-member panel on a five-point scale (1 = very thin; 5 = very fat).
[2]Live weight was adjusted to a standard body condition of 3.0 using a regression of body condition score (X_1) and height (X_2) on body weight (Y).
[3]Standard error of the mean.

could be consumed at an adequate level. Forages having somewhat lower digestibility (e.g., < 50% DDM) may not be consumed at a level adequate to supply the threshold amount.

Figure 1. Forage DM Digestibility vs Intake DMI and DDMI in all ewes



Implications

These data indicate that increased forage digestibility will not be beneficial to the grazing ruminant once a threshold level is reached. This level would be expected to be different for the different species, classes, and genotypes of animals generally in order of energy requirements per unit of live body weight.

Literature Cited

Huston, J.E. 1986. Computerized decision aids in nutrition management of range sheep. Texas Agric. Exp. Sta. Prog. Rep. PR-4410.
SAS. 1991. SAS Systems for Linear Models. SAS Inst., Inc., Cary, NC.

The Effects of Nutrition, Shearing, and Environment on Angora and Cashmere Goat Production

C.A. Taylor, Jr., J.E. Huston, C.J. Lupton, W.S. Ramsey, and T.D. Brooks

ABSTRACT

Fifty-four Cashmere and sixty Angora females were assigned across various treatment groups to determine the effects of body condition and natural cover (trees and shrub canopy) on survival, kidding rate, and fiber production of Angora and Cashmere goats sheared at two winter dates. The treatments included feeding a 14% pelleted ration at two different feed levels (full feed for half of the goats and 1.5% of body weight for the other half) to create High and Low body conditions. Half of the animals on each feed treatment were then either shorn on January 15 or February 21. Fleeces were individually sacked and will be analyzed for fiber quality at a future date. After shearing, the goats were placed either into an open pasture (canopy cover < 1%) or into a brush pasture (canopy cover > 25%). All goats were scanned with a sonagram to determine the number of fetuses/doe. Does were monitored to record abortions and early births. Kids were paired with their dams to determine reproductive losses. Angora and Cashmere goats in the High condition body treatment gained 26.5 and 28.6 lb/hd, respectively whereas those in the Low body condition treatment gained virtually zero. Angora does averaged .97 fetuses compared to 1.55 for Cashmere does. Angora does raised .61 kids to 6 wk of age, and Cashmere does raised 1.32 kids each which represents a reproductive loss of 37 and 15%, respectively. The body condition, natural cover, and shearing date appeared to have no direct effect on kid production. However, a possible breed x body condition interaction was observed for survival of adult goats after shearing. Six of seven (86%) of the adult Cashmere goats that died were in the low body condition group, and only one Angora adult died. Results of this study will become more meaningful after data are accumulated over several years.

Introduction

Goats in Texas vary in appearance and genetic potential and are perceived to differ in hardiness and resistance to various types of stress. Angora goats have a high genetic potential for fiber production, resulting in high nutritional requirements. Also, because forage is frequently of low quality, Angora goats in the Edwards Plateau region of Texas are generally undernourished throughout most of their lives unless they are provided supplemental feed. Being undernourished results in reduced reproduction, size, and fleece weight, and increased susceptibility to death from hypothermia immediately after shearing (Shelton, 1993). Cashmere goats produce significantly less fiber than Angora goats and apparently have lower nutritional requirements on a body weight basis. However, a relatively lower nutritional requirement does not necessarily reduce the shearing loss potential in cashmere goats as compared to Angoras. Factors such as body condition and protection from harsh environments may be as important to Cashmere goats as they are to Angora goats. A study is in progress to determine the interaction of management and the environment on Angora and Cashmere goat production and survival.

Experimental Procedure

A flock of 54 Cashmere does (mixed aged does) and sixty Angora does (21 mo old) were assigned randomly across various treatment groups to study how the effects of nutrition and shearing interact with environmental conditions to affect goat production (Figure 1). Breeding season for the does started October 2 and continued until November 15, 1995. After breeding and to establish High and Low body conditions, the does were assigned to 20 pens (six goats per pen based on body weight and breed) and fed a 14% pelleted ration at either 1.5% of body weight or *ad libitum* for 60 d. All goats were scanned on December 1 with a sonagram to determine the number of fetuses/doe. One half of the study goats were shorn on January 15 and placed either into a 42 acre pasture with less than 1% brush canopy cover (open pasture) or into an 80 acre pasture with greater than 25% brush canopy cover (brush pasture). The remaining goats were maintained in pens until they were shorn on February 21 and then evenly divided into the two pasture treatments. Goats were fed a supplement in both pastures to maintain body condition. Fleece characteristics of both breeds of goats will be quantified at a later date to assess the treatment effects. Does were monitored so that abortions and early births could be recorded. Kids surviving to 6 wk of age were considered to be successfully raised.

The Statistical Analysis System (SAS, 1985) General Linear Models procedures were used to analyze the data generated in this study. Duncan's Multiple Range Test was used to identify significant differences between mean values.

Results and Discussion

The feeding treatment was used to create a High and Low body condition. Goats in the High body condition gained more weight than goats in the Low body condition ($P < .01$). At the beginning of the study, the average body weight of the Angora goats was 65.7 lb compared to 104 lb for the Cashmere goats ($P = .01$). The average live body weight of the Angora goats in High body condition changed from an initial weight of 67.4 lb on October 2 to 93.9 lb on November 15 (gain = 26.5 lb), whereas the average live weight of those in Low body condition remained the same ($P = .45$; Figure 2). Body weights of Cashmere goats in High body condition changed from an initial average weight of 105.9 lb on October 2 to 134.5 lb on November 15 (gain = 28.6 lb). Those in Low body condition remained the same ($P = .40$).

Angora does averaged .97 fetuses compared to 1.55 per Cashmere doe ($P < .01$). They raised fewer ($P < .01$) kids than Cashmere does to 6 wk of age (.61 vs 1.32 per doe) reflecting a 37 and 15% kid loss for the two breeds, respectively (Figure 3). The feeding treatment effect on fetus and kid production averaged 1.3 and 1.2 fetuses/doe ($P > .10$) for the High and Low treatments, respectively, and .97 and .93 kids/doe ($P > .10$). There was no significant breed x feeding treatment interaction. The shearing treatment effect on fetus and kid production averaged 1.2 fetuses/doe for both shearing dates and 1.1 and .8 kids/doe for the January and February shearing dates, respectively ($P > .10$). There was no significant breed x shearing treatment interaction. The pasture treatments appeared to have no effect on subsequent kid production ($P > .10$).

Death losses of does were greater for the Cashmere than the Angora goats. A total of seven Cashmere goats died compared to only one Angora goat. Six of the dead Cashmere goats were from the Low body condition treatment. Of those that died, five were from the February shearing date, and four from the brush pasture. Cold dry weather occurred throughout most of the study period (Figure 4). Freezing weather occurred 4 d in a row (Jan 18 to 21) soon after the first shearing date (Jan 15). No rain fell during January, and February precipitation was below normal. March had similar temperatures as February but did receive .28 in. of precipitation; April had two consecutive days of cold wet weather. This is an ongoing project and additional years will be needed to better quantify the treatment effects. However, this first year's data support the opinion that Angora goats are more susceptible to abortions than Cashmere goats. Body condition appeared to be more important to adult goat survival than other treatments. Cashmere goats appeared to be more susceptible to hypothermia than Angora goats.

Literature Cited

SAS. 1985. SAS User's Guide: Statistics. SAS Inst., Inc. Cary, NC.

Shelton, M. 1993. Angora Goat and Mohair Production. Anchor Publishing Company. San Angelo, TX.

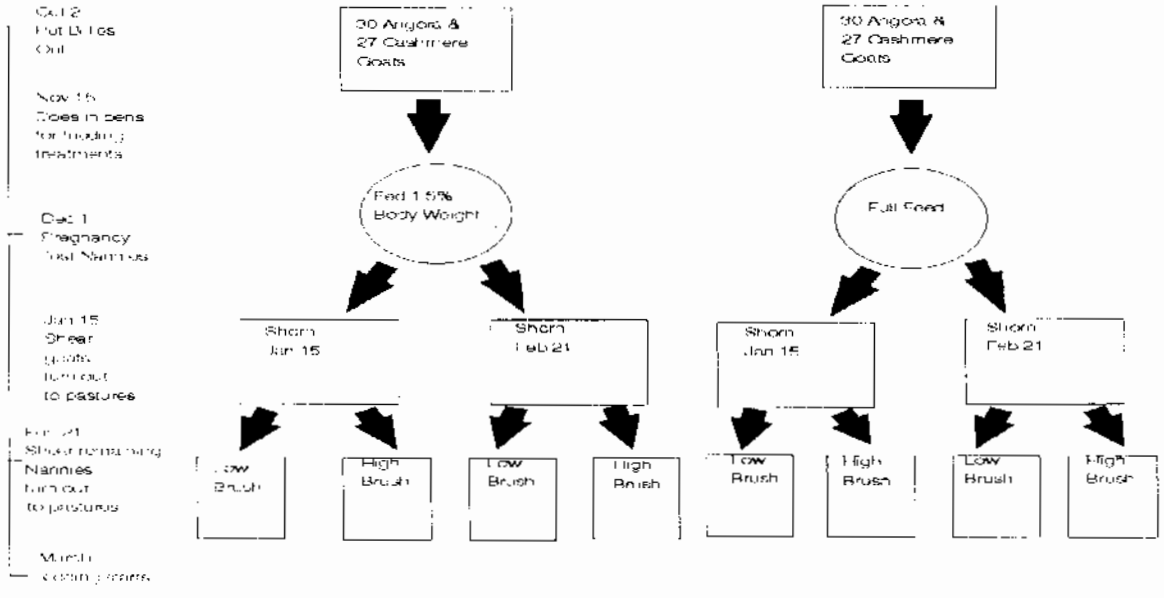


Fig. 1. Diagram for goat research.

Figure 2. Weight changes of goats during feeding portion of test

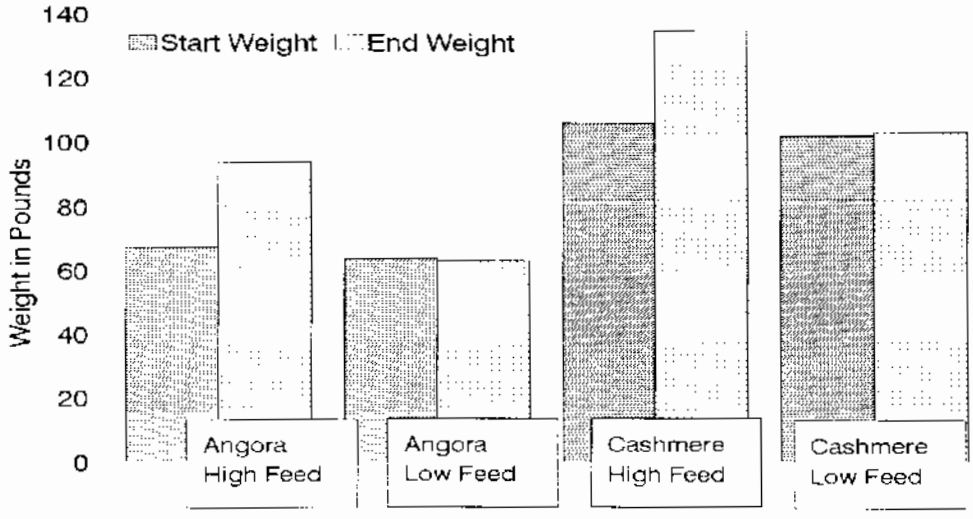


Figure 3. Number of fetuses and kids per doe

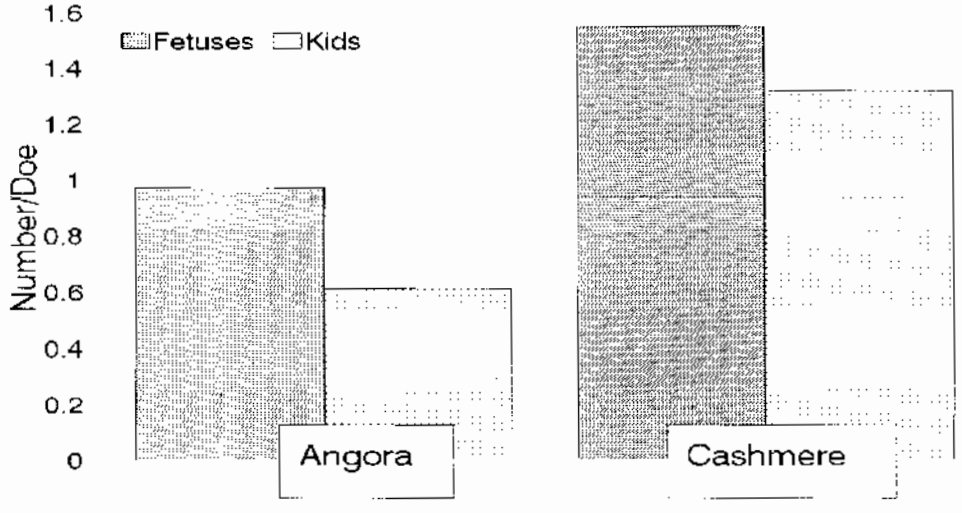
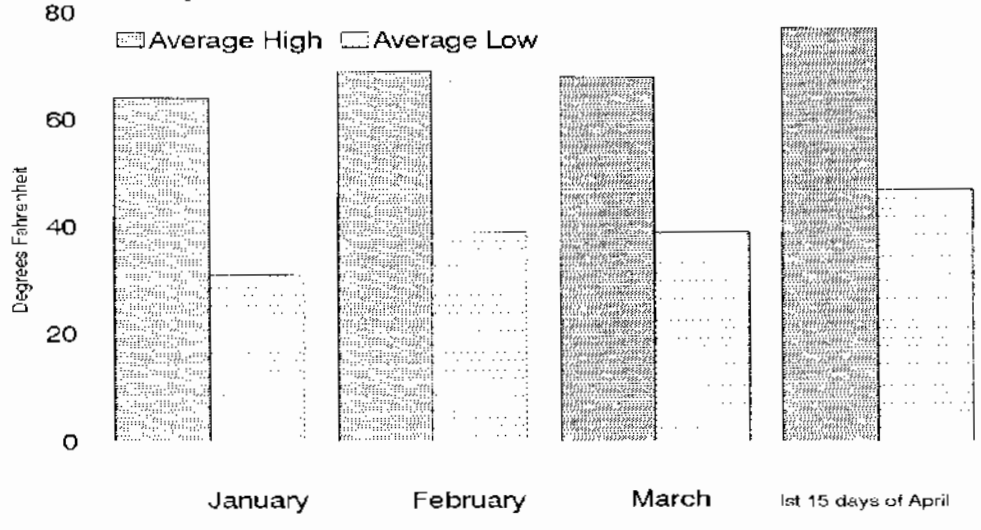


Figure 4. Average minimum and maximum temperatures for January, February, March, and April



Cotton Feed Product Composition: A Survey

M.C. Calhoun, L.A. Forster, Jr., S.W. Kuhlmann, and B.C. Baldwin, Jr.

ABSTRACT

This report contains the results of a comprehensive survey conducted during the period from 1991 to 1994 to provide reliable, up-to-date information to livestock producers, nutritionists, consultants, feed formulators, and others on nutritional and gossypol values for cottonseed, cottonseed meal and cottonseed hulls. The work was done in cooperation with the National Cottonseed Products Association and involved over 5,000 individual analyses on 83 cottonseed, 123 cottonseed meal, and 31 cottonseed hull samples collected at 40 cottonseed oil mills across the U.S.

Introduction

Cotton is a major crop grown throughout the Southern U.S. Production for 1995 was 18.0 million bales harvested from 16.0 million acres. Most of the cotton grown is Upland cotton (*Gossypium hirsutum*), but some long staple or Pima cotton (*G. barbadense*) is grown in the southwestern states. Pima represents less than 2% of U.S. cotton acreage. Cottonseed production for 1995 was 6.9 million tons. In recent years, 50 to 55% of available seed has been processed by the oil mills, and 40 to 45% has been fed directly to ruminant livestock as whole seed (NCPA, 1996). Cottonseed meal and cottonseed hulls are important by-products of cottonseed oil extraction. Cottonseed meal is used as a high protein supplement for animals, primarily ruminants, and hulls are used as a source of roughage in animal feeds. Based on current production estimates, about 2.9 million tons of cottonseed, 1.8 million tons of cottonseed meal and 1.1 million tons of cottonseed hulls were available to feed to livestock from the 1995 crop.

Reliable nutritional information is essential for formulating and manufacturing feeds. Little information is available for cottonseed hulls, and much of the information for cottonseed and cottonseed meal represents analyses done 25 to 30 yr ago. Periodic introduction of new cotton varieties during this time period has been accompanied by decreases in average seed size and oil percentage, changes that could have altered nutritional values for whole seed. The most recent comprehensive determination of nutritional values for cottonseed meals was done under the direction of the National Cottonseed Product Association (NCPA) during the 1960s (Jones, 1981). Since then there have been changes in oil extraction procedures that justify a reexamination of nutritional and gossypol values for cottonseed meals. In the mid 1960s, 51% of cottonseed was processed by screw presses, 25% by prepress solvent extraction, 22% by direct solvent extraction, and 2% by hydraulic pressing. By 1980, only 20% of the seed was processed by screwpressing, whereas prepress solvent extraction and direct solvent extraction each accounted for 40%. By the mid to late 1980s, the predominate process was direct solvent extraction. This is still the predominant process, but the last 10 yr have seen a rapid introduction of expanders into direct solvent plants. This process is now commonly referred to as the expander solvent process. Expanders dramatically reduced free gossypol levels compared with the direct solvent process without expanders.

Experimental Methods

During December 1991 and January 1992, cottonseed meal samples were obtained by the NCPA from 40 cottonseed oil mills (nine expeller, one prepress solvent, six direct solvent and twenty-four expander solvent) for a study to determine protein degradation in the rumen. Protein degradation was determined by Dr. Glen Broderick using a rumen in vitro system (Broderick, 1987). These samples were then shipped to the Texas Agricultural Experiment Station's Nutrition/Toxicology Laboratory in San Angelo, Texas, for determination of gossypol values; free and total by the Official Methods of the American Oil Chemists Society (AOCS, 1985 a,b) and (+)- and (-)-gossypol by high performance liquid chromatography (Hron et al., 1995). Finally the samples were sent to a commercial laboratory for determination of crude protein, acid detergent and neutral detergent fiber, crude fiber, ether extract and macro and micro minerals (Livestock Nutrition Services, P.O. Box 1655, Columbia, MO 65205).

In a subsequent survey, oil mills across the U.S. were asked by the NCPA to participate in a project to sample and analyze cottonseed, cottonseed hulls, and cottonseed meals during the 1993-94 processing year. Thirty-one oil mills cooperated with this project. Samples were collected over a 5-d period on three occasions during the period from November 1993 to May 1994. The first set of samples (N = 28) was collected in November and December 1993, the second set (N = 28) in January and February 1994, and the third set (N = 27) in March and April 1994. Five of the oil mills used the expeller process, one the prepress solvent process, one the direct solvent process, and 24 the direct solvent process with expanders. A total of 83 samples were collected and submitted. Not all plants submitted samples for each

collection period. Twenty-two submitted three samples, eight submitted two and one submitted only one sample.

As they were collected, samples were shipped to the Texas Agricultural Experiment Station's Research Center at San Angelo. They were subsampled and stored at -15 to -20°C until used for analyses. A basic analysis consisting of dry matter, crude protein, acid detergent fiber, neutral detergent fiber, crude fiber, ether extract, ash, and macro and micro minerals was done at the Northeast DHIA Forage Laboratory (Forage Laboratory, Northeast DHIA, 730 Warren Road, Ithaca, NY 14850). Amino acid analyses (cottonseed meals only) were done by Woodson-Tenent (Woodson-Tenent Laboratories, 345 Adams Avenue, Memphis, TN 38101). Gossypol analyses were done at the Texas Agricultural Experiment Station's Nutrition/Toxicology Laboratory in San Angelo. Free and total gossypol were determined by the Official Methods of the American Oil Chemists Society (AOCS, 1985 a,b), and the isomers of gossypol were determined by high performance liquid chromatography (Hron et al., 1995).

The 83 cottonseed and cottonseed meal samples were analyzed individually. The 83 cottonseed hull samples were composited to provide a single sample for each of the 31 oil mills. The composite samples were then analyzed. Amino acid composition was obtained for cottonseed meals from eighteen cottonseed oil mills. The sample analyzed for amino acids was a composite of the samples received from each mill.

Results and Discussion

The nutrient composition of the 83 samples of cottonseed collected during 1993-94 is presented in Table 1, along with information for whole, linted cottonseed from the most recent revisions of the United States - Canadian Tables of Feed Composition (NRC, 1982) and the Nutrient Requirements of Dairy Cattle (NRC, 1989). Values in the Nutrient Requirements of Beef Cattle (NRC, 1984) and Sheep (NRC, 1985) are very similar to those in the US-Canadian Tables. All values are on a 100% dry matter basis. The most significant changes are the lower value for ether extract and the higher values for the fiber measurements (acid detergent fiber, neutral detergent fiber and crude fiber). These changes would be expected to result in a decrease in the energy values for whole linted cottonseed (Coppock and Wilks, 1987; Weiss, 1993).

Cottonseed is naturally very low in sodium; consequently, the value (.31% Na) reported in the United States - Canadian Tables appears incorrect. The copper value (54 ppm) in these tables also appears incorrect. The iron content of cottonseed in the present survey (50 ppm) is one-third of previously published values (151 ppm).

Table 1. Nutrient composition of whole linted cottonseed[a]

	NRC		NCPA[d]				
	Dairy[b]	NRC[c]	1993-94 Survey				
Item	Cattle	1982	MEAN	SD[e]	CV[f]	MIN	MAX
Dry matter, %	92.0	92.0	91.6	.89	.97	89.4	93.1
Crude protein, %	23.0	23.9	22.5	1.07	4.76	20.7	25.8
Acid detergent fiber, %	34.0	29.0	38.8	2.38	6.14	33.9	43.3
Neutral detergent fiber, %	44.0	39.0	47.2	3.40	7.20	39.2	54.0
Crude fiber, %	24.0	20.8	29.5	2.04	6.91	24.0	33.0
Ether extract, %	20.0	23.1	17.8	1.54	8.62	13.8	21.2
Ash, %	4.8	4.8	3.8	.23	6.10	3.34	4.32
Calcium, %	.21	.16	.14	.016	10.73	.108	.190
Magnesium, %	.46	.35	.35	.020	5.81	.305	.390
Phosphorus, %	.64	.75	.56	.055	9.86	.447	.700
Potassium, %	1.00	1.21	1.14	.067	5.86	.99	1.28
Sodium, %	.01	.31	.008	.007	82.08	.003	.038
Sulfur, %	.26	.26	.20	.023	11.35	.144	.260
Copper, ppm	9	54	7	1.3	18.9	4.0	*11.9*
Iron, ppm	151	151	50	11.5	22.9	37.9	*123.0*
Manganese, ppm	19	10	15	2.2	14.9	11.8	*20.0*
Molybdenum, ppm			1.6	.52	31.4	1.0	3.8
Zinc, ppm	33	-	33	3.5	10.7	24.9	42.0

[a]Values are on a 100% dry matter basis for 83 samples collected at 31 cottonseed oil mills during 1993-94.
[b]NRC, 1989.
[c]United States - Canadian Tables of Feed Composition (NRC, 1982).
[d]National Cottonseed Products Association.
[e]Standard deviation.
[f]Coefficient of variation.

The nutrient composition of cottonseed hulls is presented in Table 2. The values are for composite samples from 31 oil mills. Information from the United States - Canadian Tables of Feed Composition (NRC, 1982) has been included for comparison. The values reported in the current revisions of the Nutrient Requirements of Dairy Cattle (NRC, 1989), Beef Cattle (NRC, 1984) and Sheep (NRC, 1985) are identical to those in the United States - Canadian Tables. Results of the current survey are similar to published values (NRC, 1982) for many nutrients; however, some of the mineral elements, particularly the trace elements are considerably different. Potassium is higher, whereas, sulfur, copper, iron, manganese, and zinc are much lower.

Table 2. Nutrient composition of cottonseed hulls[a]

Item	NRC[b]	NCPA[c] 1993-94 Survey MEAN	SD[d]	CV[e]	MIN	MAX
Dry matter, %	91.0	89.9	.87	1.0	87.7	91.5
Crude protein, %	4.1	5.0	.75	15.0	4.0	6.9
Acid detergent fiber, %	73.0	67.0	2.83	4.2	57.9	71.6
Neutral detergent fiber, %	90.0	86.9	4.13	4.8	76.3	92.6
Crude fiber, %	47.8	48.6	3.12	6.4	41.5	56.2
Ether extract, %	1.7	1.9	.66	34.7	1.0	3.3
Ash, %	2.8	2.8	.30	10.7	2.39	3.97
Calcium, %	.15	.15	.03	20.0	.10	.25
Magnesium, %	.14	.15	.02	13.3	.12	.23
Phosphorus, %	.09	.08	.04	50.0	.05	.26
Potassium, %	.87	1.13	.05	4.4	1.03	1.24
Sodium, %	.02	.009	.003	33.3	.005	.019
Sulfur, %	.09	.05	.01	20.0	.03	.10
Copper, ppm	13	3.6	.72	20.0	3.0	5.0
Iron, ppm	131	30.1	13.4	44.5	18.0	91.0
Manganese, ppm	119	16.8	3.1	18.4	12.0	22.0
Molybdenum, ppm	–	.37	.56	151.4	0	1.50
Zinc, ppm	22	9.9	2.3	23.2	6.0	19.0

[a]Values are on a 100% dry matter basis for samples submitted by 31 oil mills. Each sample was a composite of samples received from each mill.
[b]United States - Canadian Tables of Feed Composition (NRC, 1982).
[c]National Cottonseed Products Association
[d]Standard deviation.
[e]Coefficient of variation.

The nutrient composition of the 40 cottonseed meal samples obtained from the oil mills during December 1991 and January 1992, summarized by processing method, is presented in Table 3. The data in this table represent samples collected from nine expeller, one prepress solvent, six direct solvent and twenty-four expander solvent oil mills. All values are reported on a 100% dry matter basis. Because there was only one prepress solvent plant and only one sample was collected from this plant, a comparison with other processes haslimited value. However, for the other cottonseed meals, the major effects of processing appear to be on ether extract, sodium, and rumen degradable protein. The expeller process leaves more residual oil than any of the solvent processes. The higher sodium content of the solvent extracted cottonseed meals probably reflects the addition of soapstock to these meals. Undegraded protein, as estimated by a rumen in vitro system (Broderick, 1987), was higher for the expeller meal than for any of the solvent meals. This is due to the higher temperature and pressure associated with this process. The similar values for the solvent meals is hard to explain because the temperatures and pressures associated with the prepress solvent and expander solvent processes are greater than for the direct solvent process and would be anticipated to increase the percentage of protein not degraded in the rumen.

Table 3. Nutrient composition of cottonseed meals processed by different methods[a]

Item	Oil extraction procedure: Mechanical	Prepress solvent	Direct solvent	Expander solvent
Dry matter, %	93.9 (1.6)	91.6	90.3 (1.3)	90.6 (1.4)
Crude protein, %	45.8 (2.8)	41.6	49.0 (2.0)	48.4 (2.5)
Acid detergent fiber, %	17.1 (2.2)	21.4	16.1 (2.7)	16.7 (3.0)
Neutral detergent fiber, %	28.0 (2.8)	28.4	25.1 (3.7)	26.0 (4.0)
Crude fiber, %	16.4 (1.6)	19.6	15.6 (2.0)	16.1 (2.3)
Ether extract, %	5.8 (2.3)	.49	1.4 (.9)	1.2 (1.0)
Calcium, %	.20 (.03)	.24	.21 (.02)	.23 (.03)
Magnesium, %	.69 (.10)	.55	.76 (.09)	.72 (.09)
Phosphorus, %	1.26 (.25)	1.36	1.33 (.36)	1.28 (.30)
Potassium, %	1.90 (.20)	1.64	1.99 (.19)	1.91 (.23)
Sodium, %	.06 (.06)	.15	.16 (.06)	.16 (.10)
Copper, ppm	19.5 (16.8)	17.5	17.3 (3.3)	17.6 (3.0)
Iron, ppm	124 (68)	116	104 (9)	135 (61)
Manganese, ppm	24.3 (4.2)	25.7	23.7 (3.7)	23.8 (2.2)
Zinc, ppm	65.5 (3.7)	70.1	67.9 (8.5)	69.7 (6.1)
Undegraded protein[b], %	52.4 (7.6)	36.0	36.2 (3.8)	37.0 (3.2)

[a]The data in this table represents the analysis of 40 cottonseed meal samples obtained during December 1991 and January 1992 by the National Cottonseed Products Association from 40 oil mills. Values are the means for each process with the standard deviation in parentheses. Values are on a 100% dry matter basis. Samples were collected from nine mechanical (expeller process), one prepress solvent, six direct solvent, and twenty four direct solvent with expanders oil mills. All were commercial 41% protein cottonseed meals.
[b]Rumen undegraded protein was determined by Dr. Glen Broderick using a rumen in vitro system (Broderick, 1987).

Results of the basic analyses to determine the nutritional composition of cottonseed meals obtained in the 1993-94

survey are summarized by process in Tables 4, 5, and 6, respectively, for mechanically extracted, prepressed solvent extracted, and solvent extracted meals.

Table 4. Nutrient composition of mechanically extracted, 41% crude protein cottonseed meal [a,b]

Item	NCPA[c]	NRC[d]	NCPA 1993-94 Survey MEAN	SD[e]	CV[f]	MIN	MAX
Dry matter, %	91.4	93.0	92.3	1.84	2.0	89.7	95.7
Crude protein, %	44.9	44.3	46.1	1.35	2.9	43.8	48.9
Acid detergent fiber, %	–	20.0	18.1	1.99	11.0	15.1	21.3
Neutral detergent fiber, %	–	28.0	32.3	6.50	20.1	21.9	41.9
Crude fiber, %	14.8	12.8	11.4	1.09	9.6	9.7	13.0
Ether extract, %	4.1	5.0	4.6	.42	9.2	3.9	5.1
Ash, %	6.8	6.6	7.2	1.07	14.8	6.1	9.8
Calcium, %	.18	.21	.21	.03	12.4	.15	.24
Magnesium, %	.46	.58	.65	.07	10.9	.52	.75
Phosphorus, %	1.02	1.16	1.14	.13	11.4	.95	1.38
Potassium, %	1.31	1.45	1.68	.09	5.2	1.51	1.81
Sodium, %	.04	.05	.007	.002	29.6	.004	.011
Sulfur, %	–	.43	.43	.02	5.5	.39	.48
Copper, ppm	18.3	20.0	10.9	1.7	15.6	8.0	14.0
Iron, ppm	109.4	197.0	106.4	22.9	21.5	78.0	157.0
Manganese, ppm	23.6	24.0	18.7	2.0	10.6	16.0	22.0
Molybdenum, ppm	–		2.4	.64	26.5	1.3	3.7
Zinc, ppm	62.9	69.0	62.8	6.9	11.1	50.0	76.0

[a]International Feed Number. 5-01 617.
[b] Values are on a 100% dry matter basis. The data are for 14 samples collected from five oil mills.
[c]Values are for samples analyzed by the National Cottonseed Products Association during the 1960s. These are adjusted means obtained by adding (fiber, ash) or subtracting (all other nutrients) ½ standard deviation from actual means (Jones, 1981).
[d]United States - Canadian Tables of Feed Composition (NRC, 1982).
[e]Standard deviation.
[f]Coefficient of variation.

All of the cottonseed meals were commercially produced, 41% crude protein meals. Twenty-four of the oil mills using the solvent extraction process were using expanders, and one was a direct solvent plant without expanders. Because the industry does not label these as separate processes, these were combined and are presented in a single table (Table 6).

Table 5. Nutrient composition of prepressed solvent extracted, 41% crude protein cottonseed meal[a,b]

Item	NCPA[c]	NRC[d]	NCPA 1993-94 Survey MEAN	SD[e]	CV[f]	MIN	MAX
Dry matter, %	89.9	91.0	90.3	1.25	1.4	89.0	92.0
Crude protein, %	46.0	45.6	48.2	.34	.7	47.9	48.7
Acid detergent	-	19.0	19.5	1.96	10.1	16.7	21.0
Neutral detergent fiber, %	–	26.0	26.0	1.85	7.1	23.4	27.5
Crude fiber, %	15.1	14.1	12.1	.33	2.7	11.7	12.5
Ether extract, %	.7	1.3	1.7	.37	22.1	1.2	2.1
Ash, %	7.1	7.0	7.8	1.14	14.6	6.9	9.4
Calcium, %	.17	.22	.24	.01	3.4	.23	.25
Magnesium, %	.44	.55	.61	.07	11.5	.52	.69
Phosphorus, %	1.08	1.21	1.20	.15	12.7	.99	1.35
Potassium, %	1.36	1.39	1.68	.12	7.1	1.52	1.81
Sodium, %	.04	.04	.15	.05	31.7	.11	.22
Sulfur, %	–	.34	.44	.02	5.4	.42	.47
Copper, ppm	19.9	20.0	13.3	.47	3.5	13.0	14.0
Iron, ppm	122.4	223.0	154.7	62.6	40.5	105.0	243.0
Manganese, ppm	22.4	23.0	20.3	.47	2.3	20.0	21.0
Molybdenum, ppm	-	–	3.5	.54	15.3	2.80	4.10
Zinc, ppm	69.4	69.0	64.3	6.8	10.6	55.0	71.0

[a]International Feed Number. 5-07-872.
[b]Values are on a 100% dry matter basis. The data are for three samples collected from one oil mill.
[c]Values are for samples analyzed by the National Cottonseed Products Association during the 1960s. These are adjusted means obtained by adding (fiber, ash) or subtracting (all other nutrients) ½ standard deviation from actual means (Jones, 1981).
[d]United States - Canadian Tables of Feed Composition (NRC, 1982).
[e]Standard deviation.
[f]Coefficient of variation.

For comparison purposes, nutritional composition data for cottonseed meals analyzed by the NCPA during the 1960s (Jones, 1981) and from the United States - Canadian Tables of Feed Composition (NRC, 1982) were included in these tables. The NCPA data from the 1960s are not directly comparable to the NRC data or the results of the current survey because the means reported by NCPA were adjusted by either adding, in the case of fiber and ash, or subtracting, for all the other nutrients, ½ standard deviation from actual means (Jones, 1981).

Results of this survey suggest crude protein, magnesium, potassium, and sulfur are higher and crude

Table 6. Nutrient composition of solvent-extracted, 41% crude protein cottonseed meal[a,b]

Item	NCPA c	NRC d	NCPA 1993-94 Survey MEAN	SDe	CVf	MIN	MAX
Dry matter, %	90.4	91.0	89.1	.93	1.0	86.7	91.0
Crude protein,	45.8	45.2	47.6	1.99	4.2	43.0	52.4
Acid detergent fiber, %	–	–	17.3	2.70	15.6	12.2	23.9
Neutral detergent fiber, %	–	–	24.5	3.61	14.7	15.8	32.4
Crude fiber, %	13.7	13.3	11.2	1.47	13.1	8.4	15.3
Ether extract, %	1.7	1.6	2.2	.89	41.1	.6	4.7
Calcium, %	.17	.18	.22	.03	13.2	.16	.36
Magnesium, %	.44	.59	.66	.06	9.6	.49	.82
Phosphorus, %	1.08	1.21	1.20	.14	12.0	.86	1.54
Potassium, %	1.28	1.52	1.72	.11	6.4	1.45	1.98
Sodium, %	.04	.05	.14	.09	63.2	.004	.33
Copper, ppm	18.0	22.0	12.5	2.0	16.2	7.0	16.0
Iron, ppm	99.6	228.0	126.0	39.0	30.9	75.0	222.0
Manganese, ppm	22.9	23.0	20.1	2.7	13.3	14.0	25.0
Molybdenum, ppm	–	–	2.5	.80	32.0	1.3	5.1
Zinc, ppm	63.6	68.0	63.7	6.8	10.7	49.0	83.0

aInternational Feed Number. 5-01-621.
bValues are on a 100% dry matter basis. The data are for 66 samples collected from 25 oil mills.
cValues are for samples analyzed by the National Cottonseed Products Association during the 1960s. These are adjusted means obtained by adding (fiber, ash) or subtracting (all other nutrients) ½ standard deviation from actual means (Jones, 1981).
dUnited States - Canadian Tables of Feed Composition (NRC, 1982).
eStandard deviation.
fCoefficient of variation.

fiber, copper, and manganese are lower in cottonseed meals produced today compared with those 25 to 35 yr ago. The major effect of process is on fat content. The mechanically extracted cottonseed meals have a much higher residual oil content than prepressed solvent or direct solvent cottonseed meals.

Table 7 presents a summary of published information for the amino acid composition of cottonseed meals by process (NRC, 1971; Jones, 1981; NRC, 1982). In comparing the NCPA and the NRC values it is important to remember that the NCPA values are adjusted means, obtained by subtracting ½ standard deviation from the actual means (Jones, 1981). It was not possible to calculate actual means for the NCPA data because the standard deviations were not reported. All values are reported on a 100% dry matter basis. With the exception of lysine, process does not appear to have an important effect on essential amino acids. The lower values for total lysine for the mechanical process, compared with solvent processes, may reflect the increased binding to gossypol that occurs at higher temperatures and pressures.

Table 7. Amino acid composition of mechanical, prepress solvent, and direct solvent extracted cottonseed meals expressed as a percentage of dry

Amino acid	NCPA[a] Mech.	NCPA Prepress solvent	NCPA Direct solvent	NRC[b] Mech.	NRC Prepress solvent	NRC Direct solvent
Alanine	1.73	1.80	1.79	1.60	1.64	1.61
Arginine	4.74	5.10	5.15	4.51	4.71	4.62
Aspartic Acid	4.11	4.14	4.07	3.70	3.78	3.68
Cystine	.64	.71	.68	.78	.90	.85
Glutamic Acid	9.35	9.23	8.94	8.56	8.43	8.21
Glycine	1.85	1.89	1.87	2.06	2.14	2.17
Histidine	1.17	1.22	1.22	1.15	1.27	1.21
Isoleucine	1.43	1.48	1.47	1.56	1.59	1.67
Leucine	2.44	2.70	2.66	2.50	2.67	2.56
Lysine (total)	1.74	1.90	1.95	1.73	2.01	1.86
Methionine	.60	.58	.56	.62	.62	.64
Phenylalanine	2.41	2.47	2.47	2.35	2.21	2.46
Proline	1.55	1.71	1.60	1.44	1.59	1.53
Serine	1.84	1.94	1.96	1.84	2.01	1.92
Threonine	1.42	1.47	1.48	1.44	1.48	1.52
Tryptophan	.55	.52	.58	.57	.56	.61
Tyrosine	1.19	1.26	1.26	1.01	1.27	1.13
Valine	2.01	2.09	2.01	2.05	2.20	2.06
SUM	40.79	42.22	41.75	39.47	41.08	40.31

[a]Values are for samples analyzed by the National Cottonseed Products Association during the 1960s. These are adjusted means obtained by subtracting ½ standard deviation from actual means (Jones, 1981).
[b]The values for alanine, aspartic acid, glutamic acid and proline were obtained from the Atlas of Nutritional Data on United States and Canadian Feeds (NRC, 1971). All other values were obtained from the United States - Canadian Tables of Feed Composition (NRC, 1982).

Amino acid profiles for 18 cottonseed meals (three mechanical, one prepress solvent, and fourteen expander

solvent) are given in Table 8 (expressed as a percentage of dry matter) and Table 9 (expressed as a percentage of protein). The NCPA and NRC data in these tables are averages for the mechanically extracted, prepressed solvent extracted, and direct solvent extracted cottonseed meals presented in Table 7. The sample submitted for each of the 18 cottonseed meals was a composite of the samples received from each of these mills during 1993-94. Admittedly, this is a small number of samples; however, the higher value for histidine and the lower values for isoleucine, methionine, tyrosine and valine may be significantly different than the values in the NCPA and NRC publications.

Cottonseed, cottonseed meal, and cottonseed hulls all contain gossypol, a toxic, polyphenolic binaphthyl dialdehyde (Berardi and Goldblatt, 1980). Gossypol occurs throughout the cotton plant, but is concentrated in pigment glands present in cottonseed. These glands are visible as small dark specks when a seed is cut. Because of restricted rotation about the bond that joins the two naphthalene groups of the molecule, gossypol exists naturally as a mixture of two stereoisomers. These are (+)- and (-)-gossypol. The minus isomer appears to have

Table 8. Amino acid composition of cottonseed meals expressed as a percentage of dry matter

			NCPA 1993-94 Survey				
Amino acid	NCPA[a]	NRC[b]	MEAN[c]	SD[d]	CV[e]	MIN	MAX
Alanine	1.77	1.62	1.79	.119	6.6	1.59	2.05
Arginine	5.00	4.61	4.81	.264	5.5	4.35	5.33
Aspartic Acid	4.11	3.72	4.24	.194	4.6	3.99	4.72
Cystine	.68	.84	.69	.044	6.4	.61	.75
Glutamic Acid	9.17	8.40	9.08	.593	6.5	8.11	10.20
Glycine	1.87	2.12	1.87	.101	5.4	1.71	2.12
Histidine	1.21	1.21	1.50	.080	5.3	1.36	1.64
Isoleucine	1.46	1.61	1.28	.067	5.2	1.17	1.43
Leucine	2.60	2.58	2.61	.095	3.6	2.45	2.81
Lysine (total)	1.87	1.87	1.91	.172	9.0	1.56	2.19
Methionine	.58	.63	.77	.070	9.0	.67	.91
Phenylalanine	2.44	2.34	2.34	.124	5.3	2.18	2.60
Proline	1.62	1.52	1.62	.169	10.4	1.26	1.99
Serine	1.91	1.92	2.13	.099	4.6	2.02	2.39
Threonine	1.46	1.48	1.57	.070	4.4	1.46	1.75
Tryptophan	.55	.58	52	.054	10.4	.36	.60
Tyrosine	1.24	1.14	1.03	.058	5.7	.94	1.15
Valine	2.04	2.10	1.82	.091	5.0	1.66	2.00
SUM	41.58	40.29	41.59				

[a]Values are for samples analyzed by the National Cottonseed Products Association during the 1960s. These are adjusted means obtained by subtracting ½ standard deviation from actual means (Jones, 1981).
[b]The values for alanine, aspartic acid, glutamic acid, and proline were obtained from the Atlas of Nutritional Data on United States and Canadian Feeds (NRC, 1971). All other values were obtained from the United States - Canadian Tables of Feed Composition (NRC, 1982). Each value represents the average for mechanically extracted, prepressed-solvent extracted, and direct solvent extracted 41% protein cottonseed meals.
[c]The data are for samples obtained from 18 oil mills across the United States. Each sample was a composite of the samples received from each mill.
[d]Standard deviation.
[e]Coefficient of variation.

Table 9. Amino acid composition of cottonseed meals expressed as a percentage of protein

			NCPA 1993-94 Survey				
	NCPA[a]	NRC[b]	MEAN[c]	SD[d]	CV[e]	MIN	MAX
Alanine	3.88	3.56	3.74	.262	7.0	.25	4.22
Arginine	10.97	10.16	10.05	.506	5.0	.06	.98
Aspartic Acid	9.02	8.20	8.86	.366	4.1	8.49	9.71
Cystine	1.49	1.86	1.44	.087	6.1	1.22	1.55
Glutamic Acid	20.12	18.51	18.97	1.168	6.2	17.28	21.74
Glycine	4.10	4.68	3.90	.213	5.4	3.48	4.36
Histidine	2.65	2.66	3.14	.173	5.5	2.81	3.40
Isoleucine	3.20	3.54	2.68	.149	5.5	2.44	2.96
Leucine	5.70	5.68	5.46	.203	3.7	5.09	5.79
Lysine (total)	4.10	4.11	4.00	.350	8.8	3.30	4.73
Methionine	1.28	1.38	1.61	.136	8.4	1.40	1.87
Phenylalanine	5.37	5.15	4.88	.256	5.2	4.44	5.35
Proline	3.56	3.35	3.40	.384	11.3	2.60	4.25
Serine	4.19	4.24	4.46	.186	4.2	4.22	4.91
Threonine	3.20	3.26	3.29	.139	4.2	3.03	3.60
Tryptophan	1.21	1.28	1.10	.121	11.0	.72	1.28
Tyrosine	2.72	2.50	2.15	.126	5.8	1.95	2.36
Valine	4.48	4.63	3.81	.192	5.0	3.45	4.14
SUM	91.24	88.74	86.94				

[a]Values are for samples analyzed by the National Cottonseed Products Association during the 1960s. These are adjusted means obtained by subtracting ½ standard deviation from actual means (Jones, 1981).
[b]The values for alanine, aspartic acid, glutamic acid, and proline were obtained from the Atlas of Nutritional Data on United States and Canadian Feeds (NRC, 1971). All other values were obtained from the United States - Canadian Tables of Feed Composition (NRC, 1982). Each value represents the average for mechanically extracted, prepressed solvent extracted, and direct solvent extracted 41% protein cottonseed meals.
[c]The data are for samples obtained from 18 oil mills across the United States. Each sample was a composite of the samples received from each mill.
[d]Standard deviation.
[e]Coefficient of variation.

the greatest biological activity and is the isomer responsible for infertility in males (Matlin et al., 1985; Joseph et al., 1986; Lindberg et al., 1987).

Total and free gossypol, expressed as a percentage of dry matter, and (+)- and (-)-gossypol, expressed as a percentage of total gossypol are presented in Table 10. The values are means with the standard deviations in parenthesis. Cottonseed hulls contained the least total gossypol of any of the cotton by-products; but because about 46% of this was free gossypol, the free gossypol content of some of the hull samples was higher than free gossypol values for some mechanical and prepress solvent cottonseed meals. Particles of cottonseed meats not separated from hulls are believed to be the source of gossypol in cottonseed hulls.

Decorticated seed is cottonseed meats (kernels) with the outer seed coat (hulls and lint) removed. Gossypol analysis is done on decorticated seed, and this is the basis on which most laboratories report the gossypol content of cottonseed. The gossypol values for whole, linted seed in Table 10 were calculated by multiplying the percentage of gossypol in decorticated seed by .55. This value assumes the weight of decorticated seed is 55% of the weight of whole, linted seed. Total and free gossypol are essentially the same in recently harvested and properly stored whole cottonseed. Seed can be stored for many months in a cool, dry environment without altering this relationship.

Processing method does not appear to affect total gossypol, and the total gossypol content of cottonseed meals does not appear to have changed much in the last 25 to 35 yr. Processing method does affect free gossypol. The higher temperatures and pressures associated with production of mechanically extracted and prepress solvent cottonseed meals result in lower free gossypol values than for direct solvent meals. The introduction of expanders into the direct solvent process in the last decade has dramatically reduced free gossypol in cottonseed meals produced by the solvent process (Table 10).

The proportions of (+)- and (-)-gossypol in cottonseed is a varietal characteristic. Seed of the upland cottons currently grown in the U.S. average about 60% (+)- and 40% (-)-gossypol. The range of values for the isomers is 55 to 65% (+)- and 35 to 45% (-)-gossypol. Processing does not appear to affect the isomers, and the proportions of the isomers in cottonseed hulls and cottonseed meals are the same as for the seed (Table 10).

Table 10. Percentages of total and free gossypol and the proportions of gossypol isomers in cotton feed products[a]

Item	Samples, No.	Gossypol		Gossypol isomers[d]	
		Total[b]	Free[c]	(+)	(-)
		--- % ---		— % of total —	
Cottonseed hulls[e]	30	.107 (.03)	.049 (.03)	59.4 (2.7)	40.6 (2.7)
Decorticated seed[e]	83	1.20	1.24	61.2	38.8
Whole linted seed[f]	83	.66 (.05)	.68 (.05)	61.2 (2.4)	38.8 (2.4)
Mechanical CSM					
1[g]	---	1.02	.04	---	---
2[h]	9	1.18 (.18)	.04 (.01)	62.1 (1.8)	37.9 (1.8)
3[e]	14	1.09 (.12)	.06 (.01)	59.9 (2.4)	40.1 (2.4)
Prepress solvent CSM					
1[g]	---	1.13	.05	---	---
2[h]	1	.89	.03	57.6	42.4
3[e]	3	1.06 (.04)	.07 (.02)	58.1 (1.8)	41.9 (1.8)
Direct solvent CSM					
1[g]	---	1.04	.30	---	---
2[h]	6	1.21 (.27)	.15 (.08)	60.9 (1.7)	39.1 (1.7)
Expander solvent					
2[h]	24	1.19 (.14)	.10 (.03)	59.0 (2.5)	41.0 (2.5)
3[e]	66	1.16 (.14)	.14 (.04)	58.3 (2.6)	41.7 (2.6)

[a]Percentages of free and total gossypol are on a dry matter basis; (+)- and (-) gossypol are expressed as a percentage of total gossypol. Values are means with the standard deviation in parentheses.
[b]Total gossypol was determined by the Official Method of the American Oil Chemists Society (AOCS, 1985b).
[c]Free gossypol was determined by the Official Method of the American Oil Chemists Society (AOCS, 1985a).
[d](+)- and (-)-gossypol were determined by high performance liquid chromatography (Hron et al., 1995).
[e]Values are for samples collected at cottonseed oil mills during 1993-94.
[f]Values for whole, linted seed were calculated by multiplying the percentage of gossypol in decorticated seed (seed without hulls and lint) by .55.
[g]Values are for samples analyzed by the National Cottonseed Products Association during the 1960s. These are adjusted means, i.e., actual means plus ½ standard deviation.
[h]Values are for samples collected at cottonseed oil mills during 1991-92.

Acknowledgements

This research was supported by grants from the National Cottonseed Products Association, P.O. Box 172267, Memphis, TN 38187; Cotton Incorporated, 4505 Creedmoor Road, Raleigh, NC 27612 and the Texas Food and Fibers Commission, 17360 Coit Road, Dallas, TX 75252.

Literature Cited

A.O.C.S. 1985a. Determination of free gossypol. Official Method Ba 7-58. In: Official and Tentative Methods of Analysis (3rd Ed.). Am. Oil Chem. Soc., Chicago, IL.

A.O.C.S. 1985b. Determination of total gossypol. Official Method Ba 8-78. In: Official and Tentative Methods of Analysis (3rd Ed.). Am. Oil Chem. Soc., Chicago, IL.

Berardi, L.C., and L.A. Goldblatt. 1980. Gossypol. In: I.E. Liener (Ed.), Toxic Constituents of Plant Foodstuffs. (2nd Ed.) Academic Press, Inc. New York. pricklypear. 183.

Broderick, G.A. 1987. Determination of protein degradation rates using a rumen in vitro system containing inhibitors of microbial nitrogen metabolism. Br. J. Nutr. 58:463.

Coppock, C.E., and D.E. Wilks. 1987. Feeding cottonseed and cottonseed meal to dairy and beef cattle. In: E.R. Jordan (Ed.) Alternative feeds for dairy and beef cattle. p. 43. Proc. National Invitational Symposium. September 22 24, 1991. St. Louis, MO.

Hron, R.J. Sr., H.L. Kim, and M.C. Calhoun. 1995. Determination of gossypol in cottonseed products. Inform 6: 485. (Abstract).

Jones, L.A. 1981. Special cottonseed products report: Nutritional values for cottonseed meal. Feedstuffs 53(52): 19.

Joseph, A.E.A., S.A. Matlin, and P. Knox. 1986. Cytotoxicity of enantiomers of gossypol. Br. J. Cancer. 54: 511.

Lindberg, M.C., R.H. Naqvi, S.A. Matlin, R.H. Zhou, G. Bialy, and R.P. Blye. 1987. Comparative anti-fertility effects of gossypol enantiomers in male hamsters. International J. Androl. 10: 619.

Matlin, S.A., R. Zhou, G. Bialy, R.P. Blye, R.H. Naqvi, and M.C. Lindberg. 1985. (-)-Gossypol: An active male antifertility agent. Contraception 31: 141.

NCPA. 1996. The cottonseed processing industry statistical handbook. National Cottonseed Products Association Inc., Memphis, TN.

NRC. 1971. Atlas of Nutritional Data on United States and Canadian Feeds. National Academy of Sciences, Washington, DC.

NRC. 1982. United States - Canadian Tables of Feed Composition. (3rd rev Ed.). National Academy Press, Washington, DC.

NRC. 1984. Nutrient Requirements of Beef Cattle. 6th rev. Ed. National Academy Press, Washington, DC

NRC. 1985. Nutrient Requirements of Sheep. 6th rev. Ed. National Academy Press, Washington, DC

NRC. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. Ed. National Academy Press, Washington, DC

Weiss, W.P. 1993. Predicting energy value of feeds. Symposium: Prevailing concepts in energy utilization by ruminants. J. Dairy Sci. 76:1802.

Diagnosis of Ovine Lentivirus Infections

A. de la Concha-Bermejillo, R.A. Juste, and J. Kwang

ABSTRACT

Ovine progressive pneumonia (OPP) is a disease of sheep caused by ovine lentivirus (OvLV). In the present study, the sensitivity and specificity of the agar gel immunodiffusion (AGID) test were compared with that of recombinant ELISA for the diagnosis of OPP. Serum samples from OvLV or placebo experimentally inoculated lambs were collected before inoculation and weekly for 26 wk thereafter. Ovine lentivirus antibodies were determined by the AGID test, a recombinant p24-OvLV protein ELISA (rp24-ELISA) or a recombinant transmembrane-OvLV protein ELISA (rTM-ELISA). Duplicate serum samples were also submitted to a private diagnostic laboratory that uses a caprine arthritis encephalitis virus (CAEV) envelope recombinant protein ELISA (rCAEV-ELISA) for the identification of OvLV-infected sheep.

The specificity of the AGID test was always 100%, and the sensitivity ranged from 11% on post-inoculation wk 2 to 100% from post-inoculation wk 5 until the end of the experiment (average 91.5%). The specificity of the recombinant ELISA test varied depending on the recombinant OvLV protein used. While the sensitivity and specificity of the rp24-ELISA varied from 22.2 to 100% (average 87.7%) and 50 to 100% (average 94.6%), respectively, the sensitivity and specificity of rTM-ELISA test ranged from 5.5 to 100% (average 86%) and from 62.5 to 100% (average 94.9%). Surprisingly, the CAEV-ELISA missed all OPPV-infected cases. These results indicate that OvLV AGID test has a high sensitivity and specificity for the diagnosis of OPP in this experimental setting.

Introduction

Ovine progressive pneumonia (OPP) is a chronic disease of sheep caused by ovine lentivirus (OvLV). The reported seroprevalence of OPP in the U.S. is 26%, but a wide variation exists among states and among individual flocks (Cutlip et al., 1992). On the other hand, the OPP seroprevalence in Texas is only 0.5%. Nevertheless, OvLV-infected animals are frequently moved into Texas from states with high OPP prevalence.

Ovine lentivirus infection of sheep may lead to a disease complex characterized by chronic weight loss and inflammation of the lungs, lymph nodes, joints, mammary gland and the central nervous system (Cutlip et al., 1988; Oliver et al., 1981; DeMartini et al., 1993). The economic losses attributed to OPP may be due to animal deaths, depressed lamb growth because of low milk production of ewes with mastitis, losses from secondary infections, and loss of trade as a result of restrictions in the international export market. Because sheep infected with OvLV remain infected for life, early identification of infected animals is critical for the control of this infection (DeMartini et al., 1991).

Serological tests are the most frequently used methods of OPP diagnosis, and among them, the agar gel immunodiffusion (AGID) test is the most commonly used because of its low cost, simplicity, and high specificity. However, the sensitivity of the AGID test generally is considered to be low. More recently, indirect ELISA tests, using either whole virus or recombinant OvLV proteins, have come to the scene claiming a high degree of sensitivity (Zanoni et al., 1991; Houwers et al., 1982; Kwang et al., 1993). In many cases the sensitivity and specificity of serological tests are based on the use of serum samples collected from the general population in which the precise state of infection cannot be confirmed by other means. In this study, we compared the sensitivity and specificity of an AGID test with those of two recombinant ELISA tests using serum samples collected chronologically after experimental OvLV or placebo inoculation. In addition, paired serum samples were submitted to a private veterinary diagnostic laboratory that runs an ELISA test for the identification of OvLV-infected animals using a caprine arthritis encephalitis virus recombinant protein (rCAEV-ELISA).

Material and Methods

Animals and Animal Inoculation

Twenty-six Rambouillet or Rambouillet x Suffolk newborn lambs from seronegative ewes were separated from their mothers and raised on an artificial diet. Newborn lambs were randomly allocated into two groups. The first group consisting of 18 lambs was inoculated intratracheally with $1x10^6$ $TCID_{50}$ of OvLV strain 85/34. The second group consisted of eight lambs inoculated with a non-infected cell culture supernatant. Serum samples collected before inoculation and weekly for 26 wk after inoculation were assigned a code and tested blindly for the presence of OvLV antibodies by the AGID test, by two different recombinant ELISA tests, or were submitted to a private diagnostic

laboratory. Blood samples, collected every other week starting before experimental inoculation until the end of the experiment, were tested for the presence of infectious virus by standard virus isolation in tissue culture.

Ten additional 1-mo-old Rambouillet lambs were inoculated in the same way as above with OvLV dilutions (two lambs/dilution) ranging from $1x10^5$ to $1x10^1$ $TCID_{50}$, and serum samples collected weekly were tested by the AGID test.

Agar Gel Immunodiffusion Test

Serum samples were tested for the presence of OvLV antibodies by the AGID test using a commercially available kit and following recommendations by the manufacturer (Veterinary Diagnostic Technology, Inc. 4890 Wheat Ridge, CO 80033).

ELISA

An ELISA test was used to determine the antibody responses to the transmembrane (TM) and p24 OvLV-structural proteins, as previously described (Kwang et al., 1993). Briefly, microtiter plates were coated with 120 μg/well recombinant TM or p24 in .1 M sodium bicarbonate buffer (pH 9.6). The plates were then washed three times in ELISA washing solution (0.15 M NaCl, .05% Tween 20), and excess binding sites were saturated with 100 μl of 1% bovine serum albumin (BSA) in phosphate-buffered saline (pH 7.2, .15 M) for 1 h at 37 °C. After three washes, 100 μl diluted sheep serum (1:50) in 1% BSA buffer were added to each well, and plates were incubated at 37 °C for 1 h. Following a subsequent washing of the wells, 100 μl of anti-sheep immunoglobulins conjugated with horse radish peroxidase were added to each well, and plates were incubated at 37 °C for 1 h. Wells were washed again, and 100 μl of substrate solution (citric acid, 2,2'-azinobis, 3-ethyl bensthiazoline sulfonic acid, H_2O_2) were added. The color reaction was allowed to proceed at room temperature for 30 min, and the absorbance of each well at 405 nm was recorded in an automatic ELISA plate reader.

Virus Isolation

Blood mononuclear cells (BMNC) were separated by centrifugation on a Ficoll-Hypaque gradient (de la Concha-Bermejillo et al., 1995). Subsequently, a total of 4 x 10^6 separated BMNC were cocultivated with semiconfluent monolayers of goat synovial membrane (GSM) cells in 25 cm^2 tissue culture flasks for 12 d. At the end of this period, cell cultures were rinsed in Hank's balanced salt solution (HBSS), fixed in methanol, stained with Giemsa, and evaluated for the presence of syncytia. A positive score was given when at least one cell containing at least five nuclei was found (de la Concha-Bermejillo et al., 1995).

Data Analysis

The results obtained from the rTM-ELISA and the rp24-ELISA were corrected for between-plate variability by dividing the OD reading of the test samples by the OD reading of the positive control in their respective plate. Initially, cutoff points that had been determined previously (Kwang et al., 1993) were used as the positive-negative threshold for the rp24- and rTM-ELISAs. However, after realizing that under this criterion too many infected animals were scored as negative during the initial weeks after infection, new cutoff values that resulted in a better trade-off between sensitivity and specificity were established.

Results

Ovine lentivirus was re-isolated in at least two occasions from all OvLV-inoculated lambs. Virus isolation in individual lambs ranged from 2 to 12 times during the course of the experiment, and the frequency of isolation in the OvLV-inoculated experimental group was higher between post-inoculation wk 2 and 8. Ovine lentivirus was never isolated from any of the negative controls.

The results of the sensitivities and specificities of the AGID, the rp24-ELISA, and the rTM-ELISA are presented in Figures 1 and 2, respectively. Positive reactions to the core protein in the AGID test were first seen in two OvLV-inoculated lambs by 2 wk post inoculation. On wk 3 after inoculation, eight OvLV-inoculated lambs showed a weak positive reaction against the envelope (env) protein, while in eight OvLV-inoculated lambs the predominant reaction was against the core protein. By 4 wk post-inoculation, only one OvLV-inoculated animal was still negative, 10 lambs showed clear anti-p24 bands and the remaining seven reacted with different levels of intensity to the env protein. All lambs infected with 1 x 10^6 $TCID_{50}$ were positive by the AGID test by 5 wk post-inoculation and remained positive for the rest of the experiment. None of the placebo-inoculated controls showed any positive reactions in the AGID test during the experiment. Based on these results the specificity of the AGID test was always 100%. On the other hand, the sensitivity ranged from 11% on post-inoculation wk 2 to 100% from post-inoculation wk 5 until the end of the experiment (average 91.5%).

The initial cutoff points between positive and negative rp24- and rTM-ELISA OD readings were taken from a previous report; however, because under this

Figure 1. Sensitivity of the agar gel immunodiffusion (AGID) test, recombinant p24-ELISA and TM-ELISA.

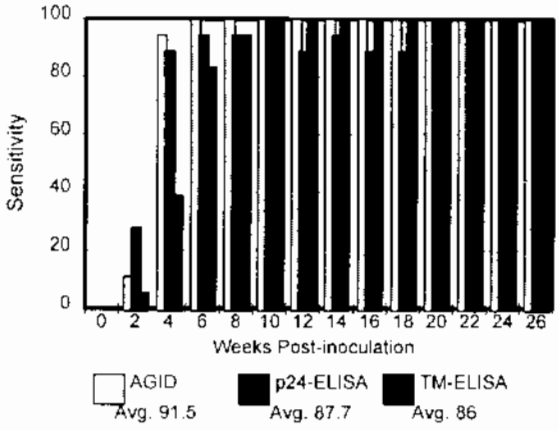


Figure 2. Specificity of the agar gel immunodiffusion (AGID) test, recombinant p24-ELISA and TM-ELISA.

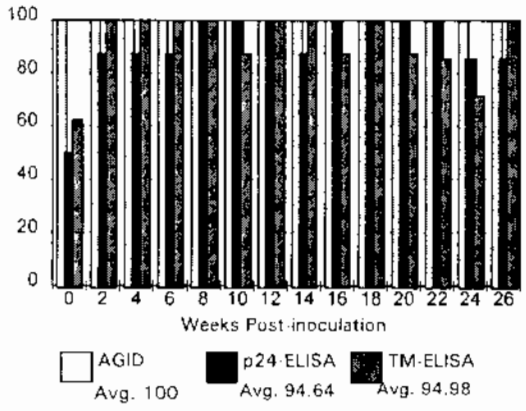


Figure 3. Determination of the cutoff value for the p24-ELISA test.

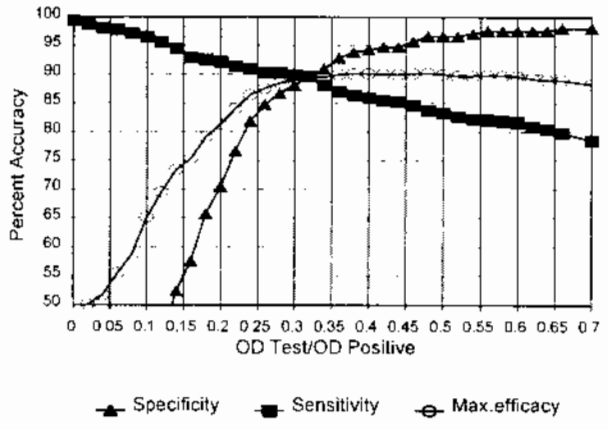
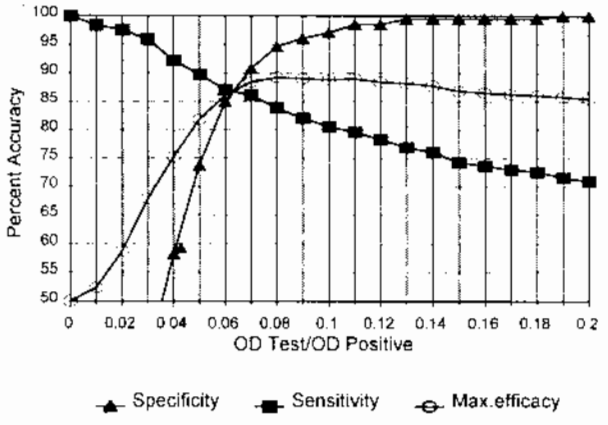


Figure 4. Determination of the cutoff value for the TM-ELISA test.



criterion many infected animals were scored as negative during the initial phases of infection, new cutoff values, to obtain the optimal trade-off between sensitivity and specificity, were established for each ELISA format by plotting the percent accuracy in the detection of infected and non-infected animals in each of the OD values (Figures 3 and 4). Based on this system a cutoff value of 0.4 for the rp24-ELISA and of 0.08 for the rTM-ELISA were selected, respectively.

The specificity of the rp24-ELISA ranged from 50 to 100% (average 94.6%) and the sensitivity from 22.2 to 100% (average 87.7%). The average specificity of the rTM-ELISA was 94.9% (range 62.5 to 100%) and the average sensitivity was 86% (range 5.5 to 100%).

In this experiment, preinoculation serum samples had a particularly high OD reading in both ELISA formats, regardless of the experimental group, resulting in specificities of 50.0 for the rp24-ELISA and of 62.5 for the rTM-ELISA during the experimental wk 0.

The time of seroconversion in lambs inoculated with 10^5 or 10^4 $TCID_{50}$ of OvLV occurred by wk 4 post-inoculation. One lamb inoculated with 10^3 $TCID_{50}$ and one lamb inoculated with 10^2 $TCID_{50}$ seroconverted at wk 5 and 4, respectively, and the other two lambs in these groups seroconverted by wk 6 post-inoculation. The two lambs inoculated with 10^1 $TCID_{50}$ seroconverted by 8 wk post-inoculation.

Discussion

The specificity of the AGID test for the detection of lentivirus infected sheep has been found to be 100% by most authors. However, its sensitivity has been reported to be lower than that of ELISA tests (Houwers et al., 1982; Kwang et al., 1993). Using experimentally lentivirus-inoculated sheep, Simard and Briscoe (1990) found that by 2 wk post-infection, 70% of the experimental animals could be detected by an indirect whole virus ELISA whereas none could be detected by AGID. The average sensitivities of these tests from wk 3 to 14 were 96% for the ELISA test and 70% for the AGID test. Similarly, increased sensitivities of an indirect whole virus ELISA and a recombinant ELISA tests over the AGID test have been found by Houwers et al. (1982) and by Kwang et al. (1993), respectively. However, false positive reactions that affect the sensitivity of some recombinant ELISA tests have been reported and ascribed to reactions to *E. coli* antigens that contaminate the recombinant viral proteins during purification (Zanoni et al., 1991).

In our study, we compared the sensitivity and specificity of a commercially available AGID test with two recombinant ELISA tests using sheep serum samples collected sequentially after OvLV or placebo inoculation. OvLV was reisolated from all virus-inoculated sheep but never from the placebo inoculated animals, thus confirming the infectious- or free-OvLV status of the animals in each of the two experimental groups. The average sensitivity (91.5%) and specificity (100%) of the AGID test were slightly superior to those of the rELISA tests. The average sensitivities and specificities of the rp24ELISA (87.4 and 94.6%, respectively) and the rTM-ELISA (86 and 94.9%, respectively) were not different ($p < .05$). The virus strain used in this experiment, OvLV-85/34 is a biological clone, meaning that it is composed of a genetically diverse population of OvLV variants or quasispecies (Woodward et al., 1995). Both antigens used for the rELISAs were originally cloned from an OvLV infectious molecular clone (Kwang and Cutlip, 1992a; Kwang and Cutlip, 1992b). Although the OvLV p24 and TM proteins carry conserved epitopes, it is possible that some immunogenic differences in the critical epitopes between strain 85/34 and the recombinant OvLV proteins existed, thus resulting in lower cross reactivity between these two OvLV strains and decreased sensitivity of the rELISA tests. This observation is supported by the fact that the relative sensitivity and specificity of the rTM-ELISA using serum samples of OvLV naturally infected sheep (where a wide range of strains may exist) were 97.6 and 100%, respectively (Kwang et al., 1993). Furthermore, this theory also could explain the reasons why the rCAEV-ELISA failed to detect all infected animals, because differences in epitope immunological cross reactivity between small ruminant lentiviruses exist. In a recent publication, the sensitivity of the CAEV AGID was higher (91.0%) than that of the OvLV AGID test (56.0%) for the detection of caprine antibody to CAEV (Knowles et al., 1994). Similarly, some CAEV recombinant antigens might fail to detect ovine antibody to OvLV. Variability in the sheep immune response to different regions of OvLV env protein has been found (Carey et al., 1993). The private veterinary diagnostic laboratory that runs the rCAEV-ELISA indicated that the antigen used for their test was a recombinant CAEV envelope protein but did not specify the characteristics. It is known that many of the epitopes in the env protein of lentiviruses are poorly conserved. Therefore, if the immunological epitopes present in the recombinant env protein of the CAEV-ELISA are different from those in the OvLV strain 85/34, the test would fail to detect infected animals. Further evidence that different proteins from small ruminant lentiviruses have different immunological cross reactivity comes from the fact that the OvLV rTM-ELISA test was more effective than the OvLV rp24-ELISA and the OvLV AGID test in identifying CAEV antibodies in the goat population (Kwang et al., 1995).

Our results indicate that the OvLV AGID has a high sensitivity and specificity for the diagnosis of OPP. Other advantages of the AGID test include its low cost and simplicity. Recombinant ELISAs varied greatly in their effectiveness to detect infected animals. Recombinant ELISA tests based on OvLV recombinant proteins had good sensitivity and specificity. The slightly lower sensitivity of the rTM-ELISA compared to the AGID test was partially due to the lower percentage of infected cases detected by the rTM-ELISA in the early stages of infection. However, the sensitivity of this test after wk 8 post-inoculation was always 100%. This delayed detection by the rTM-ELISA may be explained by the fact that ELISA tests detect only the IgG antiviral response, whereas the AGID test detects both IgM and IgG antibodies. It is well known that the initial antibody response is by IgM subsequently switching to IgG.

Because they may be easier to perform when a large number of animals are screened, ELISA tests may be the ones of choice for eradication campaigns. However, when individual infected animals need to be identified, the AGID test could be chosen. In addition, the sensitivity and specificity of ELISA tests can be manipulated by moving the cutoff value up or down depending on particular needs in each diagnostic situation. Because ELISA tests can quantify the amount

of antibody, these tests are ideal in research situations in which the kinetics of the host immune response to particular lentivirus proteins needs to be studied.

It is not clear why the OD readings in all serum samples collected at wk 0 (before inoculation) were higher than the readings at wk 1, but this suggests that serum samples from newborn lambs have a higher affinity for non-specific binding and therefore result in false positive reactions. The ELISA test based on CAEV recombinant antigens performed very poorly, indicating that each test must be carefully standardized before it can be recommended for diagnostic purposes.

In our study, all experimental lambs infected with 1 x 10^6 $TCID_{50}$ were detected as seropositive by the AGID test at 5 wk post-inoculation, indicating that delayed seroconversion or latency did not occur. Furthermore, the amount of virus inoculum seemed to have only a minor effect on the time of seroconversion. Lambs inoculated with 10^6, 10^5, or 10^4 $TCID_{50}$ of OvLV seroconverted between 2 and 5 wk post inoculation. One of each lamb inoculated with 10^3 and 10^2 $TCID_{50}$ seroconverted at wk 5 and 4, respectively, and the other two lambs in these groups seroconverted by wk 6 post-inoculation. The two lambs inoculated with 10 $TCID_{50}$ seroconverted by 8 wk post-inoculation. However, in one study in which 10% of the animals in a group of 20 sheep were found seropositive by ELISA, 70% were found positive by in situ hybridization, PCR, and cocultivation, suggesting that latent OvLV infections may occur (Johnson et al., 1992). For this reason, the roles of genotypically and phenotypically diverse OvLV strains in latency and time of seroconversion need to be further investigated.

Acknowledgments

This project was funded by a grant from the Texas Agricultural Experiment Station. A complete version of this research was published by at the Proceedings of the 99th Annual Meeting of the United States Animal Health Association. Pp 536-545, 1995. The authors would like to thank Phyllis Benge and Sue Engdahl for their assistance during the preparation of this manuscript.

Literature Cited

Carey, N., D.J. Roy, and R.G. Dalziel. 1993. Use of recombinant gp135 to study epitope-specific antibody responses to maedi visna virus. J. Virol. Meth. 43:221.

Cutlip, R.C., H.D. Lehmkuhl, M.J. Schmerr, and K.A. Brogden. 1988. Ovine progressive pneumonia (maedi-visna) in sheep. Vet. Microbiol. 17:237.

Cutlip, R.C., H.D. Lehmkuhl, J.M. Sacks, and A.L. Weaver. 1992. Seroprevalence of ovine progressive pneumonia virus in sheep in the United States as assessed by analyses of voluntary submitted samples. Am. J. Vet. Res. 53:976.

de la Concha-Bermejillo, A., S.J. Brodie, S. Magnus-Corral, R.A. Bowen, and J.C. DeMartini. 1995. Pathologic and serologic responses of isogeneic twin lambs to phenotypically distinct lentiviruses. J. Acquir. Immune Defic. Syndr. Human Retrovirol. 8:116.

DeMartini, J.C., R.A. Bowen, J.O. Carlson, and A. de la Concha-Bermejillo. 1991. Strategies for the genetic control of ovine lentivirus infections. In: Axford RFE (Ed.). Breeding for disease resistance in farm animals. p. 293. CAB.

DeMartini, J.C., S.J. Brodie, A. de la Concha-Bermejillo, J.A. Ellis, and M.D. Lairmore. 1993. Viral pathogenesis of lymphoid interstitial pneumonia in natural and experimental ovine lentivirus infection. Clin. Infect. Dis. 17 (Suppl 1):S236.

Houwers, D.J., A.L.J. Gielkens, and J. Schaake. 1982. An indirect enzyme-linked immunosorbent assay (ELISA) for the detection of antibodies to maedi-visna virus. Vet. Microbiol. 7:209.

Johnson, L.K., A.L. Meyer, and M.C. Zink. 1992. Detection of ovine lentivirus in seronegative sheep by in situ hybridization, PCR, and cocultivation with susceptible cells. Clin. Immunol. Immunopathol. 65:254.

Knowles, D.P., J.F. Evermann, C. Shropshire, J. VanderSchalie, D. Bradway, H.M. Gezon, and W.P. Cheevers. 1994. Evaluation of agar gel immunodiffusion serology using caprine and ovine lentiviral antigens for detection of antibody to caprine arthritis-encephalitis virus. J. Clin. Microbiol. 32:243.

Kwang, J., J. Keen, R.C. Cutlip, and E.T. Littledike. 1993. Evaluation of an ELISA for detection of ovine progressive pneumonia antibodies using a recombinant transmembrane envelope protein. J. Vet. Diag. Invest. 5:189.

Kwang, J., J. Keen, R.C. Cutlip, H.S. Kim, and A. de la Concha-Bermejillo. 1995. Serological diagnosis of caprine lentivirus infection by recombinant immunoassays. Small Ruminant Res. 16:171.

Kwang, J., and R. Cutlip. 1992a. Detection of antibodies to ovine lentivirus using a recombinant antigen derived from the env gene. Biochem. Biophys. Res. Commun. 183:1040.

Kwang, J. and R. Cutlip. 1992b. Analysis of antibody response to ovine lentivirus by using viral gene products expressed in a prokariotic system. Biochem. Biophys. Res. Commun. 188:20.

Oliver, R.E., J.R. Gorham, S.F. Parish, W.J. Hadlow, and O. Narayan. 1981. Ovine progressive pneumonia: pathologic and virologic studies on the naturally occurring disease. Am. J. Vet. Res. 42:1554.

Simard, C.L., and M.R. Briscoe. 1990. An enzyme-linked immunosorbent assay for detection of antibodies to maedi-visna virus in sheep. II. Comparison to conventional agar gel immunodiffusion test. Can. J. Vet. Res. 54:451.

Woodward, T.M., J.O. Carlson, A. de la Concha-Bermejillo, and J.C. DeMartini. 1995. Biological and genetic changes in ovine lentivirus strains following passage in isogeneic twin lambs. J. Acquir. Immune Defic. Syndr. Human Retrovirol. 8:124.

Zanoni, R.G., I.M. Nauta, U. Pauli, and E. Peterhans. 1991. Expression in *Escherichia coli* and sequencing of the coding region for the capsid protein of Dutch maedi-visna virus strain ZZV 1050: application of recombinant protein in enzyme-linked immunosorbent assay for the detection of caprine and ovine lentiviruses. J. Clin. Microbiol. 29:1290.

Shedding of Ovine Lentivirus in Semen of Infected Rams is Facilitated by Concurrent *Brucella ovis*-Induced Epididymitis

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

ABSTRACT

Ovine progressive pneumonia is a chronic disease of sheep caused by ovine lentivirus (OvLV). Virus shedding in semen plays a very important role in the epidemiology and transmission of several viral diseases of humans and domestic animals; however, there is no information on OvLV excretion in the semen of infected rams.

In this experiment, seven rams were used to determine if epididymitis increased the risk of shedding infectious OvLV in semen of infected rams. Rams 1 and 2 were naturally infected with OvLV. Rams 3, 4, 5, and 6 were inoculated intravenously with 1×10^6 $TCID_{50}$ of OvLV. Ram 7 was inoculated with a cell culture supernatant and used as OvLV negative control. Fourteen weeks after OvLV inoculation, rams 1, 2, 3, 6, and 7 were inoculated with 8×10^8 CFU of *Brucella ovis* into the left epididymis. Ram 4 was a natural case of *B. ovis* epididymitis, and ram 5 was left non-inoculated and used as *B. ovis* negative control.

Ovine lentivirus was demonstrated in the semen of rams 3 and 6 but only after *B. ovis* inoculation. Ovine lentivirus was isolated consistently, starting at 8 wk after virus inoculation until the end of the experiment, from blood mononuclear cells (BMNC) of rams 3 and 6, but only occasionally from rams 1, 2, 4, and 5. Semiquantitative determination of OvLV-DNA amplified by PCR from alveolar macrophages showed a higher OvLV-DNA load in rams 3 and 6 than in the other OvLV-infected rams. Collectively these results suggest that the presence of inflammatory cells in the ejaculate and a high virus load in infected animals are important factors that determine the shedding of ovine lentivirus in semen. Dissemination of OvLV through contaminated semen could have important implications in the epidemiology and control of this infection.

Introduction

Ovine progressive pneumonia is a chronic disease of sheep caused by ovine lentivirus (OvLV), also called maedi-visna or ovine progressive pneumonia virus. Ovine lentiviruses comprise a subgenus of retroviruses that share genetic, morphologic and pathogenic characteristics with the human immunodeficiency virus (HIV) and the simian immunodeficiency virus (SIV) (de la Concha-Bermejillo et al., 1995; Letvin and King, 1990; Levy, 1993a).

Venereal transmission of viral diseases is a major concern for human and veterinary medicine. In the cattle industry, in which artificial insemination is commonly used, attention has been focused on such diseases as infectious bovine rhinotracheitis (IBR) (Van Engelenburg et al., 1993; Vilcek et al., 1994; Van Oirschot et al., 1993; Van Engelenburg et al., 1995), bovine virus diarrhea (BVD) (Afshar et al., 1991; Kirkland et al., 1991), bluetongue (BT) (Akita et al., 1993; Bowen et al., 1985), and more recently bovine immunodeficiency virus (BIV) (Nash et al., 1995), where clinical signs are not always seen but detection of virus in semen is of great importance. In sheep, foot and mouth disease, vesicular stomatitis, rinderpest, peste des petits ruminants, BT, epizootic hemorrhagic disease virus, sheep pox, Rift Valley fever, Wessalbrons disease and Nairobi sheep disease have all been considered as potential threats through infected semen (Philpott, 1993). Although venereal transmission of HIV is known to be an important route of transmission, the factors that determine frequency and amount of lentivirus shedding in semen remain largely undefined (Levy, 1993a; Miller et al., 1994). Studies of rhesus macaques chronically infected with SIV show that virus-infected cells (macrophages and T lymphocytes) can be found in inflammatory lesions throughout the reproductive tract but particularly in the epididymis (Miller et al., 1994).

Ovine lentivirus is known to be transmitted through the colostrum of infected mothers to their offspring and occasionally through the placenta (Brodie et al., 1994). Increased seroprevalence in older sheep suggests that close contact transmission is also an important route of transmission (Snowder et al., 1990). Inflammatory lesions of the reproductive tract have been reported in lentivirus infected rams (Palfi et al., 1989). However, there is no information on venereal shedding and transmission of OvLV. Because the target cell for OvLV replication is the monocyte/macrophage (Clements et al., 1994), our hypothesis was that leukocytospermia would increase the risk of lentivirus shedding in semen. Brucellosis of sheep, caused by *B. ovis*, is a major cause of epididymitis and leukocytospermia in rams (Ladds, 1985). The objective of the present experiment was to study the role of epididymal inflammation in the shedding of lentiviruses in rams co-infected with OvLV and *B. ovis*.

Materials and Methods

Animals and Animal Inoculation

Seven mature rams were used in this experiment. Two rams, 1 and 2, were naturally infected with ovine lentivirus. Rams 3 to 6 were inoculated intravenously with 1 x 10^6 $TCID_{50}$ of OvLV strain 85/34. Ram 7 was inoculated with supernatant fluid from uninfected goat synovial membrane (GSM) cells and kept as the OvLV-negative control. Fourteen weeks after OvLV inoculation, rams 1, 2, 3, 5, and 7 were inoculated with 8 x 10^8 CFU of *B. ovis* directly into the left epididymis. Ram 4 was a natural case of *B. ovis* epididymitis, and ram 5 was left un-inoculated and used as the *B. ovis*-negative control. Blood, semen, and serum were collected at wk 0, 4, 6, 8, 10, 14, 15, 16, 18, 20, 36, and 44 after OvLV inoculation. The presence of infectious OvLV in blood and semen was determined by virus isolation and subsequent OvLV-DNA amplification by PCR. Leukocytospermia was evaluated by staining semen smears with Giemsa. Serum precipitating antibodies to OvLV were determined using an agar gel immunodiffusion test. Paired serum samples were submitted to the Texas Veterinary Medical Diagnostic Laboratory for detection of *B. ovis* antibodies by indirect ELISA. Seminal plasma collected at wk 0, 8, 14, 15, 16, 36, and 44 was also tested for the presence of OvLV precipitating antibodies by AGID. All rams were necropsied at wk 45 of the experiment, and tissues were collected for histologic analysis. Bronchoalveolar lavage (BAL) was performed immediately after death with sterile Hank's balanced salt solution (HBSS) pH 7.4, supplemented with 100 U/ml penicillin and 100 μg/ml streptomycin (Lairmore et al., 1986). Aliquots of BAL cells were kept frozen at -70 °C until needed for DNA extraction and PCR amplification.

Virus Isolation

A total of 4 x 10^6 Ficoll-separated BMNC or BAL cells, or 100 x 10^6 sperm cells were cocultivated with GSM cell semi-confluent monolayers in 25 cm^2 cell culture flasks for 16 h. Subsequently, non-adherent mononuclear cells and/or sperm cells were removed and GSM cells washed and incubated at 37 °C, 5% CO_2 in Dulbecco's modified Eagle Medium (D-MEM) with 10% FBS, 100 U/ml penicillin, 100 μg/ml streptomycin, and .25 μg/ml amphotericin B. Cultures were observed every other day for the presence of OvLV-associated cytopathic effect (CPE). After 12 d of incubation, GSM cells were washed, trypsinized, counted, aliquoted, and frozen for PCR analysis. Direct OvLV-DNA amplification by PCR also was performed from BAL cells collected at necropsy (de la Concha-Bermejillo et al., 1995).

Polymerase Chain Reaction

PCR was performed as previously described (Brodie et al., 1992; Brodie et al., 1995). Briefly, extraction of DNA from the GSM cells co-cultivated with BMNC or semen and from non-cultivated BAL cells was achieved with non-ionic detergents and proteinase K digestion. A volume of extracted DNA corresponding to 1.5 x 10^5 cells was used for each reaction. Ovine lentivirus primer pairs specific for the long terminal repeat (LTR) that result in the amplification of a 280 bp product were used. DNA was amplified through 25 cycles of PCR in 50 mM KCl, 10 mM Tris-HCl (pH 8.3), 2.5 mM $MgCl_2$, 200 μmol of each deoxyribonucleotide triphosphate, 10 pmoles each of upstream and downstream primer and 2.5 units of the thermostable *Thermus aquaticus* (Taq) DNA polymerase. The reactions were performed using our defined conditions. Each cycle started with a 1 min denaturation step at 95 °C, followed by cooling to and holding at 55 °C to allow primer annealing. Each cycle ended with a chain-elongation step of 3 min at 72 °C. One tenth volume of amplified DNA product was resolved by agarose gel electrophoresis and visualized by ethidium bromide staining. DNA amplified from BAL cell was subsequently transferred to a nylon membrane, hybridized to the appropriate ^{32}P riboprobe, and detected by autoradiography.

Agar Gel Immunodiffusion Test

Precipitating antibodies to OvLV capsid and envelope proteins were detected by agar gel immunodiffusion (AGID) test using a commercially available kit (Veterinary Diagnostic Technology, Inc. Wheatridge, CO).

Gross and Microscopic Assessment of Lesions

Necropsies were performed on all rams and macroscopic changes recorded. Lung, caudal mediastinal lymph node, right and left testicle, right and left epididymis, prostate gland, and spleen were fixed in 10% buffered formalin solution, sectioned at 5 μm, stained with hematoxylin and eosin, and examined using light microscopy.

Results

Results of virus isolation/PCR to detect OvLV in BMNC and semen of rams are presented in Table 1. Ovine lentivirus was isolated from BMNC of all naturally and experimentally infected rams on at least one occasion, but never from the OvLV-negative control (Ram 7). Frequency of isolation was higher in rams 3 and 6 than in any other OvLV-infected rams. In ram 3, OvLV was isolated every time it was attempted, starting at wk 6 post-inoculation; in ram 6, OvLV was isolated 7

out of 9 times during the same period. Syncytia and cell lysis could be detected in the GSM/BMNC co-cultures of these two rams within 4 to 7 d of co-culture. Ovine lentivirus was detected also in the semen of these two rams but only after *B. ovis* inoculation. In order to detect OvLV in BMNC in most other instances, amplification of OvLV-DNA by PCR from the co-cultures was necessary. Leukocytes were present in the ejaculates of all rams after experimental infection with *B. ovis* and in the naturally infected ram (ram 4) from the beginning of the study. Due to the high ratio between sperm cells and leukocytes in the ejaculate, quantification of the number of leukocytes per ml of semen was not possible. Semiquantitative amplification of OvLV-DNA extracted directly from BAL cells showed a stronger signal in rams 3 and 6. Ram 1 gave a very faint signal that was only detected by autoradiography.

Rams 1 and 2 were natural cases of OvLV infection and were seropositive by the AGID test. Rams 3 to 6, experimentally infected with OvLV 85/34, seroconverted between 6 and 8 wk post-inoculation. Ovine lentivirus precipitating antibodies were not detected in the seminal fluid of any of the experimental animals. Serum antibodies to *B. ovis* were present in ram 4 since the beginning of the experiment. All rams experimentally infected with *B. ovis* seroconverted between wk 15 and 18 of the experiment.

Gross pulmonary lesions were limited to the lungs of ram 3 and consisted of areas of severe consolidation. These areas were light gray in color, had a firmer consistency than the rest of the lung, were well demarcated, and did not float in water. On cut surface, exudate could not be extruded out of the airways. The caudal mediastinal lymph node was enlarged in this ram. Microscopic lesions consistent with those of lymphoid interstitial pneumonia (LIP) were present in the lung of ram 3, and consisted of diffuse coalescent areas of lymphoid hyperplasia and interstitial infiltration of mononuclear inflammatory cells that compressed the adjacent lung parenchyma and completely obliterated the alveolar lumen. Smooth muscle hypertrophy, interstitial fibrosis and exudation of macrophages into the alveolar lumen were also observed. Multifocal discrete areas of slight to moderate perivascular and peribronchiolar infiltration of lymphocytes were distributed throughout the lung sections of the intermediate and caudal lobes. Marked lymphofollicular hyperplasia was found in the caudal mediastinal lymph node of ram 3. The left epididymis in all *B. ovis*-inoculated rams was enlarged, and moderate to severe fibrous adhesions between the tunica albuginea and the tunica vaginales were present. Histologically, affected epididymal ducts were dilated and contained accumulated spermatozoa. Fibroplasia, diffuse infiltration of macrophages, lymphocytes, and plasma cells were found in the interstitium. Multifocal areas of severe granulomatous inflammation consisting of a central area of degenerated sperm cells, surrounded by macrophages, lymphocytes, plasma, and multinucleated giant cells were also found in the left epididymis. The left testicle of the *B. ovis*-infected rams had occasional areas of mild tubular atrophy and degeneration. The prostate gland in these rams had moderate to severe lymphoplasmacytic cellular infiltration in the lamina propria and connective tissue. Inflammatory lesions were not found in the reproductive tract of ram 7 (*B. Ovis*-negative control).

Table 1. Results of ovine lentivirus detection by a combination of virus isolation and DNA amplification by the polymerase chain reaction from blood mononuclear cells and semen in rams infected with ovine lentivirus

	Ram Number						
	1	2	3	4	5	6	7
	Week OvLV was detected in blood						
Before B. ovis	10	0, 14	6,8, 10,14	10	10	8,10	-
After B. ovis	-	---	15,16, 18,20, 36,44	15,18, 20,44	18	15,16, 18,20, 44	---
	Week OvLV was detected in semen						
Before B. ovis	---	---	---	---	-	--	---
After B. ovis	---	---	15,16, 18,36, 44	---		15,16	---

Discussion

In domestic animals, most of the reports of virus shedding in semen deal with the demonstration of the agent in the ejaculate or with the sensitivity of different tests to demonstrate these infectious agents in semen samples. However, studies to understand factors that predispose shedding of viruses are limited. In humans, despite definitive evidence of the venereal transmission of HIV, the portal of entry into the male reproductive tract and the mechanisms of transmission are not well understood. Zidovudine therapy has been associated with a marked reduction in seminal leukocyte concentration and HIV transmission (Politch et al., 1994), stressing the importance of the presence of white blood cells in the ejaculate in lentivirus shedding.

Results of the experiment reported here indicate that inflammatory lesions of the male reproductive tract predispose to shedding of OvLV in the semen of infected rams. Inflammation of the epididymis can disrupt the epididymis-blood barrier, allowing the passage of virus-

infected leukocytes, free virions in seminal plasma, and macromolecules that would otherwise be kept out of the excurrent ducts. Because monocytes/macrophages are the primary cell target of OvLV replication and because OvLV viremia is cell-associated (Clements et al., 1994; Brodie et al., 1995), we hypothesized that by inducing epididymitis, infected monocytes contaminate the semen thus carrying the virus in the ejaculate. Studies in cattle have shown that the presence of bluetongue virus (BTV) in semen is not a common event, but when it occurs, it is probably due to infected blood cells carrying the virus into the genital tract via damaged capillaries (Bowen et al., 1985). The fact that OvLV antibodies were not demonstrated in the seminal plasma in spite of being present in serum suggests that the antibody concentration in seminal plasma was much lower than in serum. Studies of paired blood and semen samples from HIV-1 seropositive men show that the antibody titer in seminal plasma is on average two logs lower than that in blood (Wolf et al., 1992). Non-suppurative prostatitis and migration of inflammatory cells through the luminal epithelium of the prostate also were observed in all *B. ovis*-infected rams; therefore, passage of OvLV from blood to semen also could have occurred at this level. Alternatively, inoculation of OvLV-infected rams with *B. ovis* may have resulted in the activation of the cytokine network and upregulation of virus expression. It has been shown that polymorphonuclear (PMN) leukocytes from HIV-seronegative donors increase HIV replication over 100-fold in chronically HIV-infected cell lines of the monocyte, T, and B cell lines. The addition of *Chlamydia trachomanis* to the co-cultures of PMN leukocytes and mononuclear cells (MNC) increased HIV replication by an additional ninefold at 24 h, whereas *C. thrachomanis* alone had no effect on p24 antigen production by MNC. It is believed that HIV replication is triggered by contact of HIV-infected cells with PMN leukocytes that in turn generate reactive oxygen intermediates and soluble factors such as TNF-α and IL-6 (Ho et al., 1995).

We did not characterize the distribution of OvLV in the different compartments of the ejaculate. Previous studies indicate that plasma viremia is a common event during HIV infections (Ho et al., 1995). Although HIV-free virions have been demonstrated in seminal plasma and HIV DNA has been shown to be carried by spermatogonia, spermatocytes, and some spermatids, HIV in semen is predominantly cell-associated, most likely with leukocytes (Mermin et al., 1991; Krieger et al., 1991; Nuovo et al., 1994; Levy, 1993b). On the other hand, free OvLV in plasma of infected sheep has not been demonstrated; therefore, it is unlikely that free-OvLV would have been present in the seminal plasma fraction of the OvLV-positive semen samples. Studies to compare the sensitivity of virus isolation and PCR to detect bovine herpes virus (BHV)-1 in bovine semen samples indicate that the PCR test detects five times as many positive samples as the virus isolation test alone (Van Engelenburg et al., 1995). However, PCR alone does not give information on the infectivity of the positive samples. In our study, to obtain the best sensitivity in detecting infectious OvLV in semen samples, we used an initial virus isolation technique followed by amplification of OvLV-DNA by PCR in the indicator cell line. Our results show that the additional PCR amplification increases the chances of obtaining a positive sample when compared to the use of virus isolation alone. In addition, we also showed that the virus shed in semen is infectious, and for this reason, the semen of infected rams may be a source of virus for non-infected animals. Venereal transmission has been shown to occur both for HIV and SIV (Alexander, 1990; Levy, 1993a). Initial observations led to the postulation that because epithelial cells of the female reproductive tract do not express the CD4 cell surface receptor, lesions in the epithelium needed to be present for sexual transmission of HIV. New evidence indicates that HIV-carrying mononuclear cells can directly infect epithelial cells of the genital tract (Pearce-Pratt and Phillips, 1993). It is likely that a similar mechanism could occur in the case of OvLV. Additional experiments are needed to determine the mechanisms and frequency of venereal transmission of OvLV.

Lesions in the reproductive tract, consisting of granulomatous epididymitis, non-suppurative prostatis, and mild testicular degeneration, were found only in the *B. ovis*-infected rams suggesting that these lesions were the result of infection with this organism and not due to OvLV inoculation. Interstitial lymphocytic infiltration in the testis has been reported in sheep infected with OvLV and in humans infected with HIV (Palfi et al., 1989; Pudney and Anderson, 1991); however, this lesion was not found in any of the OvLV-infected rams in this study.

In HIV-infected humans, infectious virus and viral antigens are detected infrequently and at lower levels in body fluids than in blood. In a recent report, HIV-1 was isolated from blood of all 34 seropositive individuals but only in 32% of semen samples from the same individuals (Krieger et al., 1991). In the present study, not all leukocytospermic OvLV-infected rams shed detectable levels of virus in the semen, suggesting that other factors may influence the frequency and relative efficiency of lentivirus shedding in semen. We found an association between the frequency of infectious OvLV isolation from BMNC, the amount of proviral DNA in BAL cells, and virus shedding in semen, indicating that virus load in the organism also plays an important role in determining the frequency of shedding of OvLV in semen. In a previous

study, seminal shedding of BTV in infected bulls closely followed peak virus titers in blood, and in no case, was BTV isolated from semen without its concurrent isolation from blood (Bowen et al., 1985). The observation that OvLV was not detected in semen samples before *B. ovis* inoculation does not rule out the possibility that the virus could have been present in minute amounts. Other factors such as stage of disease, immune status, or nutritional status may also play an important but undefined role in the shedding of lentiviruses (Alexander, 1990).

Acknowledgements

This project was funded by a grant from the Texas Agricultural Experiment Station. A complete version of this research was published by the American Journal of Veterinary Research, vol 57:684-688, 1996. The authors would like to thank Phyllis Benge and Sue Engdahl for their assistance during the preparation of this manuscript.

Literature Cited

Afshar, A., G.C. Dulac, C. Dubuc, and T.H. Howard. 1991. Comparative evaluation of the fluorescent antibody test and microtiter immunoperoxidase assay for detection of bovine viral diarrhea virus from bull semen. Can. J. Vet. Res. 55:91.

Akita, G.Y., J. Glenn, A.E. Castro, and B.I. Osburn. 1993. Detection of bluetongue virus in clinical samples by polymerase chain reaction. J. Vet. Diag. Invest. 5:154.

Alexander, N.J. 1990. Sexual transmission of human immunodeficiency virus: virus entry into the male and female genital tract. World Health Organization, Global Programme on Acquired Immune Deficiency Syndrome. Fert. Steril. 54:1.

Bowen, R.A., T.H. Howard, and V.W. Pickett. 1985. Seminal shedding of bluetongue virus in experimentally infected bulls. In: T.L. Barber, M.M. Jochim, and B.I. Osburn.(Eds.). Bluetongue and related orbiviruses. p. 91.Allan Liss, New York.

Brodie, S.J., K.A. Marcom, L.D. Pearson, B.C. Anderson, A. de la Concha-Bermejillo, J.A. Ellis, and J.C. DeMartini. 1992. Effects of virus load in the pathogenesis of lentivirus-induced lymphoid interstitial pneumonia. J. Infect. Dis. 166:531.

Brodie, S.J., A. de la Concha-Bermejillo, G. Koenig, G.D. Snowder, and J.C. DeMartini. 1994. Maternal factors associated with prenatal transmission of ovine lentivirus. J. Infect. Dis. 169:653.

Brodie, S.J., L.D. Pearson, M.C. Zink, H.M. Bickle, B.C. Anderson, K.A. Marcom, and J.C. DeMartini. 1995. Ovine lentivirus expression and disease: virus replication, but not entry, is restricted to macrophages of specific tissues. Am. J. Pathol. 146:1.

Clements, J.E., M.C. Zink, O. Narayan, and D.H. Gabuzda. 1994. Lentivirus infection of macrophages. Immunol.Series 60:589.

de la Concha-Bermejillo, A., S.J. Brodie, S. Magnus-Corral, R.A. Bowen, and J.C. DeMartini. 1995. Pathologic and serologic responses of isogeneic twin lambs to phenotypically distinct lentiviruses. J. Acquir. Immune Defic. Syndr. Human Retrovirol. 8:116.

Ho, D.D., A.U. Neumann, A.S. Perelson, W. Chen, J.M. Leonard, and M. Markowitz. 1995. Rapid turnover of plasma virions and CD4 lymphocytes in HIV-1 infection. Nature 373:123.

Ho, J.L., S. He, A. Hu, J. Geng, F.G. Basile, M.G.B. Almeida, A. Saito,Y., J. Laurence, and W.D. Johnson. 1995. Neutrophils from human immunodeficiency virus (HIV)-seronegative donors induce HIV replication from HIV-infected patients' mononuclear cells and cell lines: an in vitro model of HIV transmission facilitated by *Chlamydia trachomanis*. J. Exp. Med. 181:1493.

Kirkland, P.D., S.G. Richards, J.T. Rothwell, and D.F. Stanley. 1991. Replication of bovine viral diarrhea virus in the bovine reproductive tract and excretion of virus in semen during acute and chronic infections. Vet. Rec. 128:587.

Krieger, J.N., R.W. Coombs, A.C. Collier, S.O. Ross, K. Chaloupka, D.K. Cummings, V.L. Murphy, and L. Corey. 1991. Recovery of human immunodeficiency virus type 1 from semen: minimal impact of stage of infection and current antiviral chemotherapy. J. Infect. Dis. 163:386.

Ladds, P.W. 1985. The male genital system. In: K.V.F. Jubb, P.C. Kennedy, and N. Palmer.(Eds.). Pathology of domestic animals. p. 409.Academic Press, Inc. Orlando.

Lairmore, M.D., R.H. Rosadio, and J.C. DeMartini. 1986. Ovine lentivirus lymphoid interstitial pneumonia. Rapid induction in neonatal lambs. Am. J. Pathol. 125:173.

Letvin, N.L., and N.W. King. 1990. Immunologic and pathologic manifestations of the infection of rhesus monkeys with simian immunodeficiency virus of macaques. J. Acquir. Immune Defic. Syndr. Human Retrovirol. 3:1023.

Levy, J.A. 1993a. Pathogenesis of human immunodeficiency virus infection. Microbiol. Rev. 57:183.

Levy, J.A. 1993b. The transmission of HIV and factors influencing progression of AIDS. Am. J. Med. 95:86.

Mermin, J.H., M. Holodniy, D.A. Katzenstein, and T.C. Merigan. 1991. Detection of human immunodeficiency virus DNA and RNA in semen by the polymerase chain reaction. J. Infect. Dis. 164:769.

Miller, C.J., P. Vogel, N.J. Alexander, S. Dandekar, A.G. Hendrickx, and P.A. Marx. 1994. Pathology and localization of simian immunodeficiency virus in the reproductive tract of chronically infected male macaques. Lab. Invest. 70:255.

Nash, J.W., L.A. Hanson, and K. St.Cyr Coats. 1995. Bovine immunodeficiency virus in stud bull semen. Am. J. Vet. Res. 56:760.

Nuovo, G.J., J. Becker, A. Simsir, M. Margiotta, G. Khalife, and M. Shevchuk. 1994. HIV-1 nucleic acids localize to the spermatogonia and their progeny. Am. J. Pathol. 144:1142.

Palfi, V., R. Glavits, and I. Hajtos. 1989. Testicular lesions in rams infected by maedi/visna virus. Acta Vet Hungarica 37:97.

Pearce-Pratt, R., and D.M. Phillips. 1993. Studies of adhesion of lymphocytic cells: implications for sexual transmission of human immunodeficiency virus. Biol. Reprod. 48:431.

Philpott, M. 1993. The dangers of disease transmission by artificial insemination and embryo transfer. Br. Vet. J. 149:339.

Politch, J.A., K.H. Mayer, A.F. Abbott, and D.J. Anderson. 1994. The effects of disease progression and zidovudine therapy on semen quality in human immunodeficiency virus type 1 seropositive men. Fert. Steril. 61:922.

Pudney, J., and D. Anderson. 1991. Orchitis and human immunodeficiency virus type 1 infected cells in reproductive tissues from men with the acquired immune deficiency syndrome. Am. J. Pathol. 139:149.

Snowder, G.D., N.L. Gates, H.A. Glimp, and J.R. Gorham. 1990. Prevalence and effect of subclinical ovine progressive pneumonia virus infection on ewe wool and lamb production. J. Am. Vet. Med. Assn. 197:475.

Van Engelenburg, F.A.C., R.K. Maes, J.T. Van Oirschot, and F.A.M. Rijsewijk. 1993. Development of rapid and sensitive polymerase chain reaction assay for the detection of bovine herpesvirus type 1 in bovine semen. J. Clin. Microbiol. 31:3129.

Van Engelenburg, F.A.C., F.W. Van Schie, F.A.M. Rijsewijk, and J.T. Van Oirschot. 1995. Excretion of bovine herpesvirus 1 in semen is detected much longer by PCR than by virus isolation. J. Clin. Microbiol. 33:308.

Van Oirschot, J.T., P.J. Straver, J.A.H. Van Lieshout, J. Quak, F. Westenbrink, and A.C.A. Van Exsel. 1993. A subclinical infection of bulls with bovine herpesvirus type 1 at an artificial insemination centre. Vet. Rec. 132:32.

Vilcek, S., P.F. Nettleton, J.A. Herring, and A.J. Herring. 1994. Rapid detection of bovine herpesvirus 1 (BHV 1) using the polymerase chain reaction. Vet. Microbiol. 42:53.

Wolf, H., K. Mayer, G. Seage, J. Politch, C.R. Horsburgh, and D. Anderson. 1992. A comparison of HIV-1 antibody classes, titers, and specificities in paired semen and blood samples from HIV-1 seropositive men. J. Acquir. Immune Defic. Synd. 5:65.

Adding Value to Wool Clips by Fleece Skirting and Classing

C.J. Lupton, F.A. Pfeiffer, and S. Byrns

ABSTRACT

For each of the past four years, the Texas Agricultural Experiment Station (TAES) has sold its wool clip in two distinct forms. About 15% (3,600 lb/yr) has been sold with minimal preparation as "original bag" (OB) wool. The bulk of the clip (~19,000 lb/yr) was sold after skirting and classing. This report documents the results of TAES wool sales during this period.

Introduction

From 1986 to 1990, the TAES conducted studies to establish the technical and economic effects of various levels of fleece skirting and classing. Skirting is the practice of removing inferior wool (stains, tags, skin pieces, shanks, and heavy vegetable contamination) from the bulk of the fleece. Classing involves the grouping of properly skirted like wools for commercial marketing purposes according to several wool characteristics: staple length, strength, average fiber diameter, yield, color, and style. The results of our studies were published in technical journals, progress reports, and the popular press and have been discussed on numerous occasions at field days as well as national meetings (e.g., Pfeiffer *et al.*, 1988; Lupton *et al.*, 1989; Lupton *et al.*, 1992). Based on the results of our own research and the documented experiences of other researchers and producers, a policy decision was made in 1991 to attempt to optimize TAES wool income by skirting and classing most TAES wool prior to marketing. In order to continue the evaluation of these value-adding practices, some wool from one or more of the flocks was not skirted or classed but delivered to the warehouse each year in "original bag" (OB) form.

Procedures

The TAES maintains sheep flocks for research purposes at several West Texas locations close to San Angelo, Barnhart, Brady, and Sonora. Most of the ewes are Rambouillets although strong- and fine-wool Merino influences were introduced into one flock 6 yr ago and Booroola Merino into another. Most of the sheep are shorn once a year, one flock being shorn in January and the rest in April or early May. From 1992 to 1995, the bulk of the wool was skirted, classed, and baled by certified classers. About 15% of the clip was minimally skirted (heavy dung locks, high vegetable matter (> 6%) bellies, and floor sweepings only were removed from the main fleece line), packaged in wool sacks, and delivered to the warehouse to be sold in OB form. The warehouses to which the OB wools were delivered have traditionally specialized in selling wool in this form. Conversely, the prepared wools were marketed at warehouses having a history of handling skirted and classed wools. Average prices for the OB and skirted and classed clips were calculated in each of the 4 yr.

Results and Discussion

Overall, the characteristics of our main-line, staple wools have fallen within the following ranges during the past 4 yr:

Average fiber diameter, μm: 19.5 to 21.5
(64's to 70's)
Yield, %: 48 to 63
Vegetable matter, %: .5 to 4.5.

A summary of sale results and associated poundages are presented in Table 1. The type of detailed records that were kept during this period and that permitted calculation of average prices are presented in Table 2 (1994 data).

Table 1 shows that weight-averaged prices for the skirted and classed wool were 15% higher than for OB wool over the 4-yr period. In the past, this added income was magnified by incentive payments. Future decisions on wool preparation will have to consider the loss of the Wool Act. Timing of the sale within a year is very important, as is evidenced in the 1995 column of Table 1. In 1995, the Experiment Station failed to sell some of the skirted and classed wool during the normal high activity period of May and June. These wools were committed for sale in December at the "guaranteed minimum price" option offered by the marketing organization. The result was $ .59/lb less than the May price.

At least one major wool company still prefers to purchase OB wools. Other companies have stated preferences for skirted or skirted and classed wools. Consequently, there are producers in both camps. Some are still undecided on how best to optimize their income from wool. These data are targeted primarily at this group of producers who are in the best position to incorporate their individual labor and other costs into the overall calculation.

Two other points should also be part of the decision-making process. If skirting and classing is to be conducted, it must be done by properly trained personnel. Secondly, producers going to the trouble and expense of having their wool skirted and classed should be sure to

have the main lines objectively measured for yield and average fiber diameter before selling. This is the only objective way the buyer can offer top price. It is also the only way the producer can be sure he or she is getting paid for the true value of their clip. The size and number of main lines will determine to a large extent the economic feasibility of this practice.

Conclusions

Compared to OB wool, the sale of skirted and classed wool produced higher gross returns in each of four production years (1992 to 1995). The magnitude of the added value was variable among years ranging from +$ .09 to .30 per greasy lb of wool, this being equivalent to a range in price differentials for the OB and prepared products of 6.6 to 26.9%.

The increased financial returns from skirted and classed wool are offset by the extra expense and trouble of performing these tasks. Individual producers are in a unique position to calculate these costs and determine potential profitability of skirting and classing in their own operations.

Literature Cited

Pfeiffer, F.A, C.J. Lupton, and N.E. Blakeman. 1988. Skirting of Texas fine-wools. Texas Agric. Exp. Sta. Prog. Rep. 4585.

Lupton, C.J., F.A. Pfeiffer, and N.E. Blakeman. 1989. Optimizing the value of grease wool through preparation and marketing. SID Res. J. 5, Special Issue: 1-20.

Lupton, C.J., F.A. Pfeiffer, N.E. Blakeman, D.N. Ueckert, and J.E. Huston. 1992. Effects of skirting on yield, fineness and value of wool from fine-wool range ewes. J. Anim. Sci. 70:3657.

Table 1. Prices received for OB and skirted and classed wools over a 4-yr period by the Texas Agricultural Experiment Station, San Angelo

Item	1992	1993	1994	1995	
OB poundage	3231	8395	1170	1482	
Payment mailed	5 to11/92	6/14 to 19/93	6/29/94	5/23/95	
Average price, $/lb	1.0532	.6741	1.1165	1.3557	
USDA quoted range for OB, $/lb	1.13 to 1.24	.70 to .81	1.13 to 1.35	1.48 to 1.73	
Skirted and classed poundage	21,150	15,473	20,199		19,420
Payment mailed	5 to 10/92	5 to 12/93	5-7/94	6 to 7/95	GMP*
Average price, $/lb	1.1831	.7731	1.4151	1.4455	.8519

*GMP = Guaranteed minimum prices, 12/31/95.

Fiber Diameter Measurements of Fine-wool Rams on Performance Test

C.J. Lupton, D.F. Waldron, and F.A. Pfeiffer

ABSTRACT

Average fiber diameter (AFD), standard deviation of fiber diameter (SD), and coefficient of variation of fiber diameter (CV) were determined for core-sampled pre-test fleeces, side and britch on-test samples, and core-sampled post-test fleeces for 531 rams participating in the Texas Agricultural Experiment Station's Ram Performance Test during the years 1994, 1995, and 1996. Pre-test fleece measurements were shown not to provide a good indication of the AFD of wool grown during the test. Further, although side and post-test core samples were significantly correlated ($r^2 = .75$) in terms of AFD, side samples were coarser (1.33 μm, $P < .0001$) than whole fleece core samples. Britch and side AFD differences were not indicative of whole fleece variability of AFD ($r^2 < .04$). These last two observations have important implications for the fine-wool ram performance tests conducted by the Texas Agricultural Experiment Station (TAES) and the University of Wyoming (UW).

Introduction

Average fiber diameter and standard deviation of fiber diameter are important price-determining characteristics of raw wool because (together with length characteristics) they govern the size and uniformity of yarn, the efficiency of yarn production, and ultimately the type of product that can be manufactured from a particular lot of wool (Iman *et al.*, 1990; Lupton, 1995). Consequently, AFD and fiber diameter variability, either SD or coefficient of variation (CV), are two of the variables used to assess overall merit of fine-wool rams on performance test (Riley *et al.*, 1996). In the TAES Performance Test (Shelton and Lewis, 1986; Waldron and Lupton, 1996), the AFD of a side sample is used to estimate AFD of the fleece grown during the test. The difference between AFD of a britch sample and that of the corresponding side sample is used as a measure of fiber diameter variability. In addition, the AFD of side and britch samples constitute two independent culling levels (24.94 and 26.39 μm, respectively) for certification of rams in the American Rambouillet Sheep Breeders'Association. Previous work (Lupton *et al.*, 1990) on a limited number (100) of rams participating in the 1989 TAES test and rams (78) in the 1989 UW performance test (Iman *et al.*, 1990) indicated that AFD of side sample was a good indicator ($r = .89$) of AFD of whole fleeces and that the difference in AFD between britch and side was significantly but only poorly correlated ($r = .15$) with whole-fleece CV of fiber diameter. In contrast, the CV of fiber diameter of the whole fleece core sample was moderately correlated ($r = .45$) to the CV of fiber diameter of the side sample. One implication for fine-wool ram testing and selection of stud rams was that the CV of fiber diameter of the whole fleece is not a sensitive indicator of coarse britch wool (and vice versa).

The current 3-yr study was designed to establish the relationships between AFD and variability of fiber diameter for fleeces collected at the beginning of performance tests, side and britch samples collected during the performance tests, and whole fleeces shorn at the end of the tests. Results from this experiment will permit informed recommendations to be made concerning the use of the most appropriate measures of fiber diameter distribution in fine-wool selection programs and/or index equations.

Procedures

Rams participating in the 1994, 1995, and 1996 TAES Ram Performance Tests were routinely shorn at the beginning of the test. The "pre-test" fleeces were expected to be variable as a result of different pre-test management practices, environments, ages, and genetic backgrounds of the rams. Thirty-two ½-in core samples were removed from each pre-test fleece. The core samples (PRC) were washed and dried (ASTM, 1995), conditioned, sub-sampled with a 2-mm mini-corer, and the resulting sub-samples were measured for AFD, SD, and CV using an Optical Fibre Diameter Analyser (OFDA; IWTO, 1995). Ninety-eight days into the performance tests, mid-side (S) and britch (B) samples were removed from each ram. These wool samples were sub-sampled close to the base of the staple using a 2 mm "snippeter" device. This sampling site was chosen because it is known that AFD of a side sample of a ram on test tends to be constant after the first 28 d (Schafer, 1992; Bohnert, 1994). The resulting 2 mm snippets were cleaned with solvents (1, 1, 1-trichloroethane, ethanol, and acetone), dried, conditioned, and measured for AFD, SD, and CV using the OFDA. At the end of the 143-d performance tests, each ram was shorn. These post-test fleeces were core sampled (POC) and measured in an identical manner to the pre-test fleeces.

Data were analyzed to provide simple statistics (mean, SD and CV) for each variable measured. In addition, simple linear regression and analyses of variance were performed on the data using procedures of SAS (SAS, 1992).

Results and Discussion

Tables 1, 2, and 3 show least squares means and standard errors by year for AFD, SD, and CV of the PRC, S, B, and POC samples, respectively. Overall, the AFD of the PRC did not differ among years ($P > .05$). In contrast, mean side sample AFD in 1995 was less than 1994 or 1996 ($P < .05$). Britch AFD had a similar pattern, but core samples from the whole fleece indicated that 1994 fleeces were finer ($P < .05$) than the other two years. For the 3 yr of testing (Table 4), wool produced during the test (POC) was 2.20 µm coarser than that shorn from the animal at the start of the test. Britch samples were 2.97 µm coarser than side samples, and side samples were 1.33 µm coarser than post-test core samples of the whole fleece (POC). The observed consistent coarseness of the side sample compared to the fleece as a whole is contrary to earlier observations on rams participating in performance tests. However, a similar observation has been made previously for crossbred ewes under range conditions (Iman *et al.*, 1990). Yearly trends in SD of fiber diameter shown in Table 2 tend to follow closely the trends in AFD. The CV data (SD/AFD X 100) summarizedin Table 3 confirms that the variability in side and britch samples is generally less than that observed for either of the core samples.

Although AFD of pre-test core, side, britch, and post-test core samples differ, regression analysis confirmed that the measurements are significantly correlated. A selection of pertinent regression equations and their corresponding coefficients of determination (r^2) are given in Table 5. Only 43% of the variation in S AFD can be accounted for by the variability of PRC AFD (Table 5 and Figure 1). In contrast, 75% of the variation in S AFD is accounted for by variation in POC AFD (Table 5 and Figure 2). The two measures of variability of fiber diameter (SD and CV) invariably exhibit lower r^2 values than the corresponding AFD correlation.

The differences between side and britch AFD values were thought to be a reasonable indicator of variability of fiber diameter in the fleeces as a whole. The two regression equations at the bottom of Table 5 and Figure 3, show that such is not the case. This observation is in agreement with that made by Iman *et al.* in 1990. Measures of whole-fleece variability of fiber diameter are best determined by measuring representative core samples.

Table 1. Least squares means of average fiber diameters by year[1]

Year	N	PRC (µm)	S (µm)	B (µm)	POC (µm)
1994	201	19.95 (.10)	23.71^{a} (.13)	26.97^{a} (.17)	22.06^{b}(.11)
1995	169	20.20 (.11)	23.27^{b} (.15)	26.23^{b} (.18)	22.43^{a} (.12)
1996	161	20.20 (.11)	23.94^{a} (.15)	$26.56^{a,b}$ (.18)	22.48^{a} (.12)

[1]N = number of rams in performance test; PRC = pre-test core sample; S = side sample; B = britch sample; POC = post-test core sample.
[a,b,c]Column means having different superscripts differ ($P < .05$).

Table 2. Least squares means of standard deviation of fiber diameter by year[1]

Year	N	PRC (µm)	S (µm)	B (µm)	POC (µm)
1994	201	4.63^{a} (.04)	4.34^{a} (.04)	5.66^{a} (.06)	4.42 (.04)
1995	169	4.04^{b} (.05)	3.76^{c} (.04)	4.54^{b} (.07)	4.48 (.04)
1996	161	4.05^{b} (.05)	3.97^{b} (.04)	4.72^{b} (.07)	4.43 (.04)

[1]N = number of rams in performance test; PRC = pre-test core sample; S = side sample; B = britch sample; POC = post-test core sample.
[a,b,c]Column means having different superscripts differ ($P < .05$).

Table 3. Least squares means of coefficient of variation of fiber diameter by year[1]

Year	N	PRC (µm)	S (µm)	B (µm)	POC (µm)
1994	201	23.21^{a} (.19)	18.31^{a} (.12)	20.95^{a} (.19)	20.04 (.14)
1995	169	20.00^{b} (.21)	16.17^{c} (.13)	17.31^{b} (.21)	20.00 (.15)
1996	161	20.03^{b} (.21)	16.57^{b} (.13)	17.33^{b} (.21)	19.72 (.16)

[1]N = number of rams in performance test; PRC = pre-test core sample; S = side sample; B = britch sample; POC = post-test core sample.
[a,b,c]Column means having different superscripts differ ($P < .05$).

Table 4. Least squares means of average fiber diameter, standard deviation, and coefficient of variation for 531 ram fleeces

Item	PRC[1]	S	B	POC
AFD, μm	20.11[d]	23.64[b]	26.61[a]	22.30[c]
SD, μm	4.27[c]	4.04[d]	5.02[a]	4.44[b]
CV, %	21.23[a]	17.10[d]	18.81[c]	19.95[b]

[1]PRC = pre-test core sample; S = side sample; B = britch sample; and, POC = post-test core sample.
[a,b,c,d]Row means having different superscripts differ (P < .05).

Table 5. Simple linear regression equations and coefficients of determination (r^2) for various measures of average fiber diameter, standard deviation, and coefficient of variation[1]

Dependent variable		r^2
Average fiber diameter		
S	= 6.03 + .88 PRC	.43
S	= 5.15 + .67 B	.74
S	= -.61 + 1.09 POC	.75
Standard deviation		
S	= 2.19 + .43 PRC	.27
S	= 2.01 + .40 B	.55
S	= 1.90 + .48 POC	.21
Coefficient of variation		
S	= 11.10 + .28 PRC	.21
S	= 9.15 + .42 B	.47
S	= 11.24 + .29 POC	.09
POC SD	= 4.17 + .09 (B AFD - S AFD)	.04
POC CV	= 19.48 + .15 (B AFD - S AFD)	.01

[1]S = Side sample; PRC = pre-test core sample; B = britch sample; POC = post-test core sample; AFD = average fiber diameter; SD = standard deviation of fiber diameter; and, CV = coefficient of variation of fiber diameter

Implications

In terms of fiber diameter and its associated variability, rams participating in the TAES and UW performance tests are being assessed using different criteria. Because these criteria are used to certify the rams in a common association (The American Rambouillet Sheep Breeders' Association), some corrective measures need to be taken. Preferably, this would be done without lowering current standards that have been in effect for many years. One suggested solution for future ram tests would be as follows. First,both testing agencies would measure AFD and CV of side, britch, and whole fleeces. The current certification standards based on side and britch AFD measurements would be retained. However, the TAES index equation would be modified to match the UW equation in which AFD and CV of whole fleeces are used instead of AFD of side samples and (britch-side) AFD differences. In general, measures of fiber diameter variability are expected to become more important to breeders and processors as measurement methods become more efficient.

References

ASTM. 1995. D584. Standard test method for wool content of raw wool - laboratory scale. Annual Book of ASTM Standards.Sec. 7, Vol. 07.01:190. ASTM, Philadelphia, PA.

Bohnert, D.W. 1994. Effects of supplemental zinc on performance and fiber production of Rambouillet sheep and Angora goats. M.S. Thesis. Angelo State Univ.

Iman, N.Y., R.H. Stobart, C.L. Johnson, W.C. Russell, C.J. Lupton, and M. Shelton. 1990. Prediction of variation of fiber diameter in wool fleeces. SID Sheep Res. J. 6, 3:1.

IWTO. 1995. Measurement of the mean and distribution of fibre diameter of wool using an Optical Fibre Diameter Analyser (OFDA). IWTO-47-95. International Wool Secretariat. Ilkley, UK.

Lupton, C.J., N.E. Blakeman, F.A. Pfeiffer, and M. Shelton. 1990. Prediction of variation of fiber diameter in wool fleeces. Texas Agric. Exp. Sta. Prog. Rep. 4795.

Lupton, C.J. 1995. Standard deviation of fiber diameter and other characteristics of United States wool. Sheep and Goat Res. J. 11, 3:111.

Riley, M., H. Nel, R. Stobart, N. Taylor, and R. Townsend. 1996. 34th Wyoming Ram Test Report. Univ. of Wyoming.

SAS. 1992. SAS User's Guide: Statistics (Version 6.03). SAS Inst., Inc. Cary, NC.

Schafer, M.T. 1992. Effects of protein sources with and without yeast culture on wool production and performance of Rambouillet rams. M.S. Thesis. Angelo State Univ.

Figure 1. Side sample (SAFD) versus pre-test core average fiber diameter (PTCAFD).

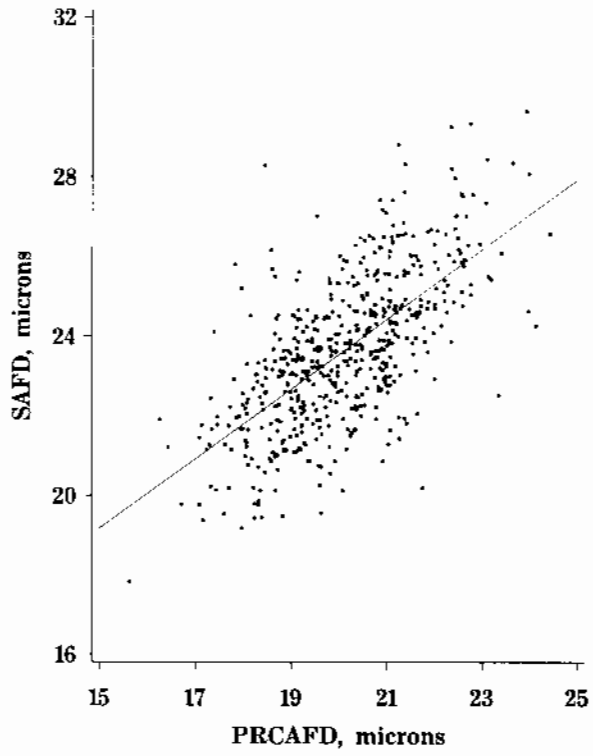


Figure 2. Side sample (SAFD) versus post-test core average fiber diameter (POCAFD).

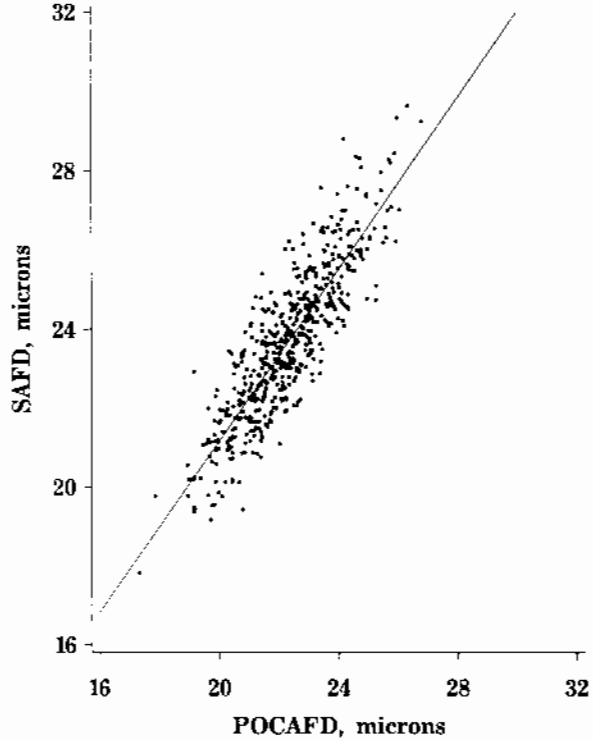
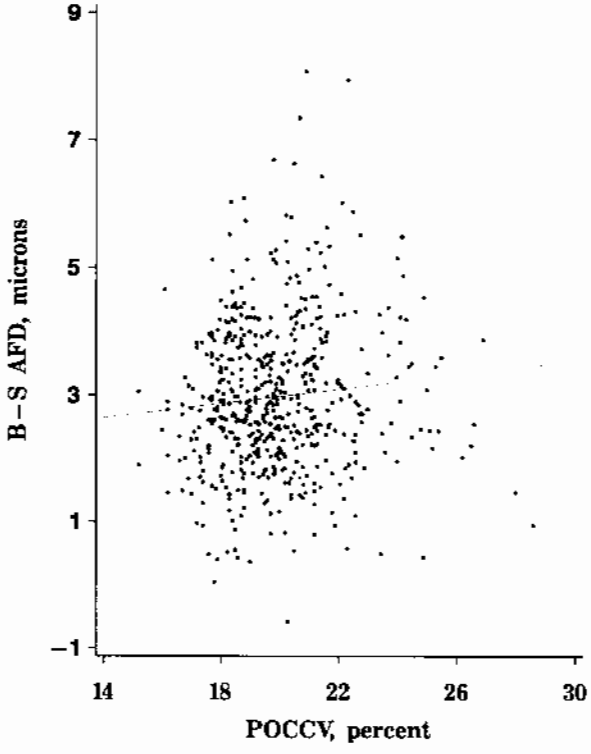


Figure 3. Britch minus side average fiber (B-S AFD) versus coefficient of variation of fiber diameter for whole fleece (POCCV).



Fiber Diameter Measurements of Angora Goats on Performance Test

C.J. Lupton, D.F. Waldron, and F.A. Pfeiffer

ABSTRACT

Average fiber diameters (AFD) and variabilities (standard deviation, SD and coefficient of variation, CV) of fiber diameter were measured on the fleeces of 301 male Angora goats participating in the 1994 and 1995 Angora Goat Performance Tests conducted by the Texas Agricultural Experiment Station. This was achieved by core-sampling each fleece and measuring a representative sub-sample using an Optical Fibre Diameter Analyser. These values were then compared with comparable measurements that had been made on neck, side, and britch samples removed halfway through the test. Average fiber diameters measured on core samples were highly and significantly correlated with each individual and the average of the three measurements made on neck, side, and britch samples. The same was true for the measures of fiber diameter variability (SD and CV). However, the variability among neck, side, and britch average fiber diameters (traditionally used as an indicator of fleece uniformity) were poorly correlated with variability of fiber diameter in the fleece core sample (CSD). The most accurate way to estimate the average fiber diameter and variability of a mohair fleece is to measure a representative core sample. Implications of these results for the performance test are given in a later section.

Introduction

Performance testing using objective measurements of economically important traits provides useful information for making selection decisions. An Angora goat performance test was begun by the Texas Agricultural Experiment Station (TAES) in 1967, discontinued in the early seventies and restarted in 1980. The program emphasizes the value of selecting males on their overall merit rather than focusing on a single trait (Lewis and Shelton, 1985). Since its inception, fiber diameter measurements were made on samples removed from the neck, side, and britch regions about halfway through the test. This practice is rationalized as follows. Taking the samples 8 wk before the end of the test provided the lab adequate time to make all the fiber diameter measurements. This much time was necessary when a projection microscope technique was being used. Measuring samples taken at three distinct places was thought to provide a good indicator of mohair uniformity in the fleece as a whole. Averaging the three measurements was considered to provide a number that would be close to the true average fiber diameter of the whole fleece grown during the test period. This value was then used in the index equation for ranking animals on overall merit. In recent years, whenever one or more of the three average fiber diameter measurements exceeded 50 μm, the goat became ineligible for certification (Waldron and Lupton, 1995).

For several years, the TAES Wool and Mohair Research Lab has been equipped with instrumentation that can measure mohair average fiber diameter and distribution much more rapidly than the projection microscope. Thus, the requirement of sampling at the midpoint of the test is no longer necessary. Fleeces grown during the test period can now be fully quantified in terms of yield, average fiber diameter, and medullated fibers in less than 3 wk.

An experiment was designed to study the relationships among average fiber diameters measured on the neck, side, britch and whole fleeces, as well as to compare variability of fiber diameter in the whole fleece to those measures of variability determined for the neck, side, and britch samples and the traditional indicator of variability (i.e., variation among neck, side, and britch average fiber diameters).

Methods

Mohair samples (approximately 3 in X 3 in) were removed from the neck, side, and britch regions of each goat participating in the 1994 and 1995 Angora Goat Performance Tests conducted at the TAES, Sonora facility. Each sample (representing 8 wk growth) was subsampled close to the base of the staple, cleaned, conditioned, and measured for average fiber diameter (AFD), standard deviation of fiber diameter (SD), and coefficient of variation of fiber diameter (CV). Subsequently, 112-d fleeces were shorn from the animals and cored (with 32 ½-in coring tubes) to obtain a sample representative of the whole fleece. This sample was cleaned in a standard manner (ASTM, 1995), conditioned, and measured for AFD, SD, and CV. The Optical Fibre Diameter Analyser (OFDA) was used to make all the measurements in both years of the experiment (IWTO, 1995). Simple statistics were calculated for each of the variables measured and linear regression and analyses of variance were accomplished using procedures of SAS (SAS, 1992).

Table 1. Minimum and maximum values, means, and standard deviations for core, neck, side, and britch average fiber diameters (AFD), standard deviations (SD), and coefficients of variation (CV) of fiber diameter

Items	Min	Max	Mean	SD
Core				
AFD, μm	29.5	57.0	39.9	3.9
SD, μm	7.8	17.2	11.0	1.6
CV, %	20.7	37.5	27.6	2.9
Neck				
AFD, μm	28.1	59.4	41.4	5.3
SD, μm	6.1	17.4	10.2	2.0
CV, %	16.5	39.3	24.7	4.0
Side				
AFD, μm	27.0	56.3	39.7	4.9
SD, μm	6.1	17.3	9.5	1.7
CV, %	15.9	36.7	24.1	3.8
Britch				
AFD, μm	28.9	64.0	44.5	5.9
SD, μm	6.9	22.7	12.3	2.4
CV, %	17.0	51.6	28.0	5.6
Average of three body locations				
AFD, μm	28.0	59.0	41.9	5.1
SD, μm	6.5	18.7	10.7	1.8
CV, %	17.9	38.0	25.6	3.9

Results and Discussion

Data from the 301 animals completing the 1994 and 1995 performance tests were analyzed. A summary of the simple statistics is given in Table 1. In terms of magnitude, the average fiber diameter of the fleece core sample (CAFD) was not different than that of the side of the neck sample (NAFD), 4.6 μm < AFD of the britch sample (BAFD), and 2.0 μm < the mean AFD of the neck, side, and britch samples (AAFD). The last value (AAFD) is the one used in the index equation to rank animals. As expected, the variability of fiber diameter in the core sample (CV) is greater than in either the neck or side samples. However, it is comparable in magnitude (27.6 vs 28.0%) to that measured for mohair growing in the britch region. This study confirms that fibers from the britch of Angora goats are the coarsest and most variable mohair tested (beard hair excluded).

In terms of year differences, all 1994 average fiber diameters and standard deviations of fiber diameter were greater than those measured in 1995 ($P < .0016$). The coefficients of variation of fiber diameter were unaffected by year ($P > .26$).

Table 2 and Figure 1 show that CAFD and AAFD are highly correlated. More than 84% of the variation in CAFD can be accounted for by the variation in AAFD. The CAFD is also significantly correlated with SAFD, NAFD, and BAFD (r^2 = .8190, .7785, and .6673, respectively). Any one of these measures of AFD could be used to give a fair estimate of CAFD, but AAFD would give a better estimate than any of the three individual measures. Nevertheless, the estimate would not be perfect (because $r^2 \neq 1$) and CAFD would best be determined by measuring it directly.

Table 2. Linear relationships between various measures of average fiber diameter and variability of fiber diameter[1]

Dependent variable		Intercept		Slope		Independent variable	r^2
CAFD	=	10.03	+	.71	X	AAFD	.8461
CAFD	=	13.05	+	.65	X	NAFD	.7785
CAFD	=	10.89	+	.73	X	SAFD	.8190
CAFD	=	15.89	+	.54	X	BAFD	.6673
CSD	=	3.41	+	.71	X	ASD	.6679
CSD	=	10.82	+	.08	X	STD	.0049
CCV	=	13.15	+	.56	X	ACV	.6040

[1]Key to abbreviations:
CAFD = average fiber diameter of the fleece core sample; AAFD = average of the neck, side, and britch average fiber diameters; NAFD = average fiber diameter of the neck sample; SAFD = average fiber diameter of the side sample; BAFD = average fiber diameter of the britch sample; CSD = standard deviation of fiber diameter of the fleece core sample; ASD = average of the neck, side, and britch standard deviations of fiber diameter; STD = standard deviation of the neck, side, and britch average fiber diameters; CCV = coefficient of variation of fiber diameter of the fleece core sample; ACV = average of the neck, side, and britch coefficients of variation of fiber diameter; r^2 = coefficient of determination.

Variability of fiber diameter in the core samples is described by CSD and CCV. The CSD values are significantly correlated with average standard deviation of diameter values measured on neck, side, and britch samples (ASD; r^2 = .6679, Figure 2). The correlation between CCV and ACV is also quite high (r^2 = .6040). However, because the correlations are not perfect, the best estimate of variability of fiber diameter in the whole fleece would also best be measured directly.

In the past, neither ASD nor ACV values have been available in the performance test report. A more traditional method of gauging variability (or uniformity) of mohair fiber diameter in these test animals has been to mentally compare the neck, side, and britch average fiber diameters. Table 2 and Figure 3 show that the correlation between actual variability of fiber diameter in the fleece (CSD) and the variability among neck, side, and britch average fiber diameters (STD) is very poor. In other words, comparing the average fiber diameters of the neck, side, and britch sample is a very poor method of estimating fiber diameter variability in the fleece as a whole. The CSD is calculated from fibers obtained in a manner so as to be representative of the entire fleece. The STD cannot separate bucks that have a small area of coarse fiber from those that have a large area of coarse fiber.

Implications

Because the TAES Wool and Mohair Research Lab is now equipped with an instrument that permits relatively high-speed measurement of fiber diameter parameters, it is no longer necessary to sample the animals at the mid-point of the test. Measuring a core sample of the fleece shorn at the end of the test would provide more accurate estimates of average fiber diameter and variability in the fleece compared to those measurements currently being obtained on neck, side, and britch samples.

Literature Cited

ASTM. 1995. Standard test method D584 for wool content of raw wool -laboratory scale. Annual Book of ASTM Standards. 07.01:190-194. ASTM, Philadelphia.

IWTO. 1995. Measurement of mean and distribution of fibre diameter of wool using an Optical Fibre Diameter Analyser (OFDA). IWTO-47-95. International Wool Secretariat, Ilkley, UK.

Lewis, R. and M. Shelton. 1985. A review of four years work in Angora performance testing. Texas Agric. Exp. Sta. Res. Cen. Tech. Rep. 85-1.

SAS. 1992. SAS User's Guide: Statistics (Version 6.03). SAS Inst., Inc. Cary, NC.

Waldron, D.F., and C.J. Lupton. 1995. Angora goat peformance test report. Texas Agric. Exp. Sta. Res. Cen. Tech. Rep. 95-2.

Figure 1. Average of fiber diameter at three locations (AAFD) versus core sample average fiber diameter.

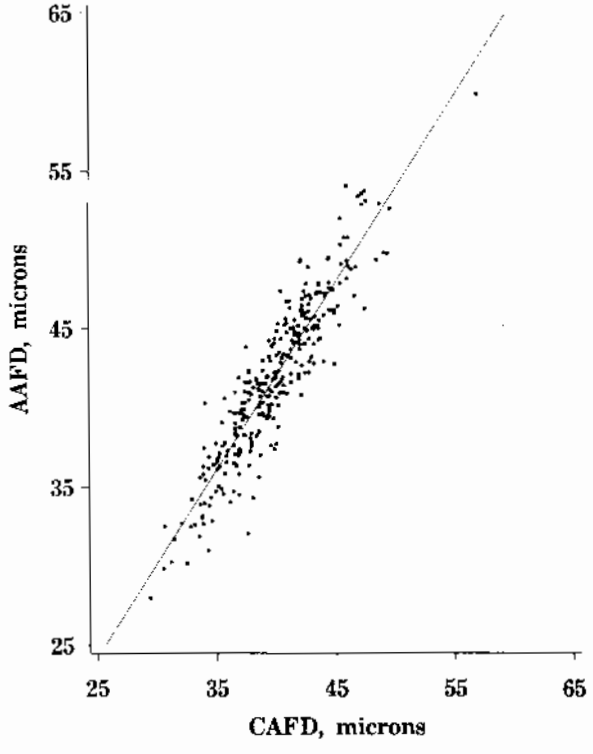


Figure 2. Average of standard deviation of fiber diameter at three locations (ASD) versus core sample standard deviation (CSD).

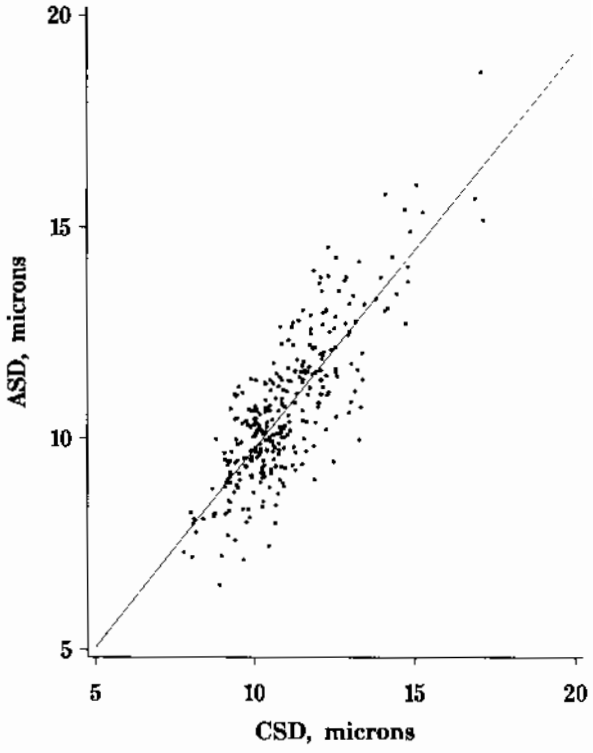
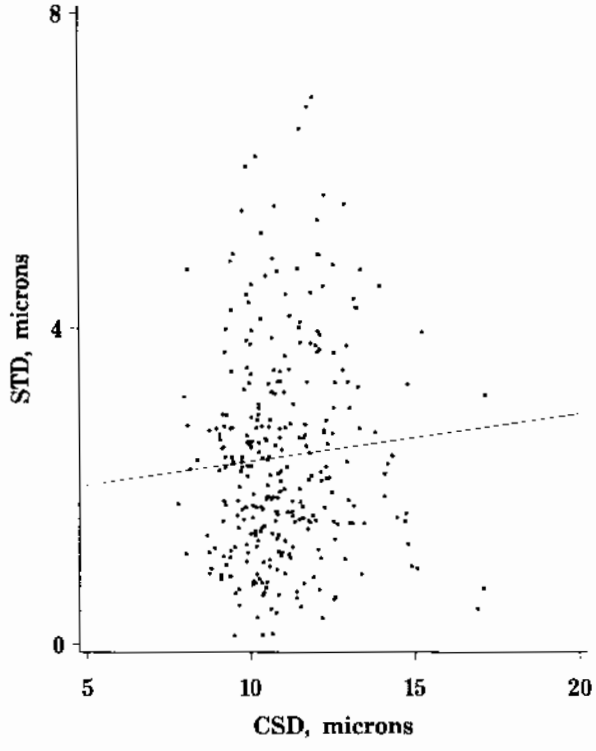


Figure 3. Standard deviation of average fiber diameter for three locations (STD) versus core sample standard deviation of fiber diameter (CSD).



Determination of Medullation in Wool and Mohair Using an Optical Fibre Diameter Analyser (OFDA)

C.J. Lupton, F.A. Pfeiffer, and S.J. Lewis.

Medullated fiber measurements are important quality determinants affecting appearance and performance (e.g., dyeability and resilience) of wool and mohair fabrics. Currently, these measurements are made manually using a projection microscope. Because the technique is slow, labor intensive, and expensive, relatively few fibers per sample (1,000) are observed and measured in normal commercial practice. Consequently, the accuracy of such measurements is relatively poor. Automatic image analysis has been demonstrated to be a very versatile technology for measuring a wide range of fiber properties (Qi *et al.*, 1995). The Optical Fibre Diameter Analyser (OFDA), a commercially available instrument incorporating this technology, has been programmed to measure fiber diameter, fiber curvature, and fiber opacity distributions. This latter capability has been utilized by several researchers for estimating medullation in wool (Edmunds, 1995) and mohair (Brims and Peterson, 1994; Peterson and Gherardi, 1995) because the opacity of a fiber increases as its degree of medullation increases. This research brief describes our preliminary evaluation of an OFDA instrument for rapid and accurate estimation of medullation in wool and mohair using a single opacity calibration.

Opacity distributions of medullated wool and mohair (five samples each selected to represent a broad spectrum of medullation, .6 to 26.50%) were measured using the OFDA after calibration with a slide of known opacity. The distributions were then used to estimate med (OFDAM), kemp (OFDAK), and total medullated (OFDAT) fiber content. Fibers having opacity > 80% and widths greater than the sample mean were considered to be medullated. Objectionable kemp fibers were those having opacities > 94%. The OFDA estimates were compared with projection microscope (PM)-determined med (PMM), kemp (PMK), and total medullated (PMT) fiber contents. The PM measurements were made on five representative subsamples (1,000 fibers each) of each of the 10 fiber samples and OFDA opacity measurements were made on two mini-cored subsamples (measured 3 times each and approximately 10,000 fibers per individual measurement). The wool and mohair samples exhibited broad ranges of med, kemp, and total medullation (.5 to 17.4, .1 to 9.1, and .6 to 26.5%, respectively). The OFDA underestimated total medullated (6.7 vs 9.1%) and med fibers (4.1 vs 6.5%) but OFDAK values (2.6%) were not different ($P > .9$) than PMK. All three estimates, OFDAM, OFDAK, and OFDAT were highly and significantly ($P < .001$) correlated with their PM counterparts ($r^2 = .981$, .964, and .981, respectively). The corresponding standard errors of prediction were .47, .31, and .68%. Times for determining medullation parameters ranged from 50 to 150 min per sample for the PM and averaged 8 min using the OFDA. These results confirm that the OFDA is a promising system for accurate and relatively rapid estimation of medullation in wool and mohair. An international round trial (Turpie, 1995) is currently in progress that will assist us in developing a standard method of test that will be acceptable to both the wool and mohair industries. Our own efforts are directed at evaluating the method for measuring low but commercially important levels of med (0 to 5%) and kemp (0 to 1%) in mohair.

References

Brims, M., and A.D. Peterson. 1994. Measuring fiber opacity and medullation using OFDA–theory and experimental results in mohair. IWTO, New Delhi, India.

Edmunds, A.R. 1995. OFDA measurement of additional fibre parameters: some preliminary results. IWTO, Harrogate, UK.

Peterson, A.D., and S.G. Gherardi. 1995. Using the OFDA to measure medullation in mohair. Abstracts, 9th. Int. Wool Text. Res. Conf., Biella, Italy:255.

Qi, K., C.J. Lupton, F.A. Pfeiffer, D.L. Minikhiem, N.S. Kumar, and A.D. Whittaker. 1995. Automatic Image Analysis System for objective measurement of animal fibers. Sheep and Goat Res. J. 11, 2:71.

Turpie, D.W.F. 1995. Report on round trial no. 1 of the working group on objectionable medullated fibres. IWTO, Nice, France.

Residual Insecticide Concentrations in Raw Fleeces, Scouring Liquor, and Scoured Wool Following Application Three Weeks before Shearing

C.J. Lupton, J.E. Huston, F.A. Pfeiffer, and K.W. Bales

ABSTRACT

Five Rambouillet ewes per treatment group were either not sprayed, sprayed with water, or sprayed with one of two organophosphorus insecticides (malathion and diazinon) at recommended (.5%) or high (1.5%) application concentrations 3 wk prior to shearing. These untimely applications were made in order to establish insecticide concentrations 1) in the fleeces at shearing time (shearer exposure levels), 2) in the fleeces after scouring (textile worker exposure levels), and 3) in the scouring liquor (potential for inclusion into lanolin-based products). Analyses showed that most of the applied insecticides degraded in the period between spraying and shearing with malathion decaying at a faster rate than diazinon. An initial concentration of 5,000 ppm of insecticide decreased to 6.25 ppm in 3 wk in the case of malathion and 127 ppm for diazinon. Malathion was not detectable (less than .05 ppm) in any of the scoured wool samples. Diazinon was present (.06 to .83 ppm) in four of the six scoured wool samples. Malathion was detected in the scouring liquor of the two groups sprayed with this insecticide at levels ranging from .03 to .11 ppm. Diazinon was detected (.20 to 11.56 ppm) in the scouring liquor from all groups.

This experiment shows that these two commonly used organophosphorus insecticides degrade rapidly in the fleeces of sheep. However, when applied at the recommended levels 3 wk before shearing, some active chemicals are still present at shearing time causing undesirable exposure to shearers and wool handlers. Diazinon, being more stable than malathion, poses a greater potential problem. Aqueous scouring of wool treated in this way reduces insecticide levels below 1 ppm in the scoured wool. However, insecticide in the scouring liquor would tend to concentrate in the wool grease fraction thus causing unacceptable contamination of lanolin products.

Applying organophosphorus insecticides to sheep a short time before shearing is not advisable because it causes exposure of workers to insecticides and contamination of products made from wool grease. If treatment with pesticides is absolutely essential in the 3 mo before shearing, synthetic pyrethroids (e.g., Ectrin) should be used rather than organophosphates.

Introduction

In many areas throughout the world, the use of pesticides to protect sheep from external parasites is essential for maintaining animal health and production of high quality wool. It has been estimated that high levels of pesticide are present in 5% of Australian wool sale lots (Russell *et al.*, 1995). This 5% of wool contributes 50% of the total pesticide residue in that nation's clip. While attempting to downplay the problem, the Australian Wool Residue Management Council has stated that strategies will be adopted to halve current levels of pesticide residues in the clip within 2 yr. The presence of pesticides in wool products has the potential to cause problems at several stages in the wool harvesting, sales, and processing pipelines (Russell, 1990, 1994). Perhaps more importantly, the public perception of pesticides in wool products has the potential of seriously damaging wool's "natural" image. A recent controlled trial in Australia concluded that late-season (9 mo or more wool) applications (backline and jetting techniques) are largely responsible for high residue levels.

In Texas, only a small proportion of sheep producers treat their animals for external parasites (Craddock, 1995). Current Texas Agricultural Extension Service recommendations (Fuchs *et al.*, 1990) for control of lice, ticks, and keds on sheep include immersing, spraying, or dusting animals within 30 d after shearing with appropriate concentrations and forms of coumaphos, diazinon, fenvalerate, malathion, methoxychlor, or permethrin. The recommendation to spray soon after shearing was made to ensure better access to the insects by the chemicals. Retention of insecticides in shorn fleeces was probably not a major consideration at the time these recommendations were formulated. Coumaphos is the only chemical recommended for spot treatment of the other common external parasites of sheep, wound infesting larvae and fleece worms. Nationally, recommended treatments for fly strike, keds, lice, mange mites, and ticks also involve application of the following chemicals: fenvalerate, coumaphos, organophosphates, and pyrethroids (ASI, 1988). Little quantitative data are available on the extent and type of residual insecticides in U.S. wool as received at the warehouses or supplied to the mills. Spraying wool with organophosphates to avoid damage due to wool moths is common practice in many storage areas.

In a 1992 pesticide audit conducted for the American Sheep Industry Association (ASI), Cunningham (1994) reported on pesticide levels in 16 scoured wools and their associated concentrated scouring effluents. Samples representative of wool production in 13 states were provided by Yocom-McColl Testing Labs., Inc., Denver,

CO. Analyses for 25 organochlorine and organophosphorus pesticides were conducted by the Warren Analytical Laboratory, Greeley, CO. No pesticides were detected in scoured wool samples (detection limits .01 or .05 ppm). For the liquid samples, minute quantities of Lindane (up to .27 ppb), chlorpyrifos (up to 4.3 ppb), diazinon (up to .31 ppb), and 4, 4'-DDE (up to .18 ppb) were detected (detection limits .05 or .25 ppb) in some of the concentrated scouring effluents. Story (1992) reported on a 1-yr study conducted at Wellman, Inc., Johnsonville, SC, in which several hundred samples of wool grease had been analyzed for pesticides (also at the Warren Analytical Laboratory, but in this case testing for the presence of 34 pesticides). His general conclusions were as follows: 1. U.S. wool grease has low levels of pesticides; 2. wool grease imported from Australian scourers usually contains very high levels of pesticides; 3. wool grease imported from Europe and from South America usually has fairly high levels of pesticides; 4. Australian wool scoured in the U.S. generally produces wool grease having acceptable levels of pesticides; 5. for the most part, diazinon is the greatest problem; 6. organochlorine pesticides (e.g., Lindane) in problem concentrations (greater than 10 ppm) are rare but have shown up in some European greases.

At least part of the conclusions might be explained by the Australian policy of not exporting grease wool containing excessive levels of insecticide. Presumably, such wools are scoured in Australia thus contributing to Story's second and fourth observations. To qualify as United States Pharmacopoeia (USP) Lanolin, refined wool grease may not contain more than 10 ppm of any one of 34 listed pesticides, nor more than a total of 40 ppm of any combination of all 34 pesticides. The Federal Drug Administrations's list of 34 pesticides does not include any pyrethroids or carbamates. These compounds generally have a short lifetime, are relatively nontoxic to humans, and produce harmless residues on decomposition. Organochlorine (OC) pesticides (e.g. Lindane, DDT) are potentially the most hazardous because of their longevity in the environment and other species-specific problems. Wellman's concern for pesticide residues in wool grease, communicated to the ASI and others by Story, provided the main impetus for the current study.

Pesticide concentrations are of primary concern at four distinct stages. First, pesticide in the greasy wool; to date, no domestic regulations exist limiting the concentration of pesticides at this stage. Australian regulations are being developed to protect shearers and wool handlers from exposure to pesticides. The tolerance level for malathion in most food crops is 8 ppm. Secondly, pesticide concentrations in scouring plant effluent; in Texas, no specific regulation covers this area. However, each situation is considered individually by local, state and federal authorities and maximum levels for pesticides (as well as chemical oxygen demand, biochemical oxygen demand, etc.) are specified in the effluent permit, these being dependent on the individual plant's and local authority's abilities to remove the contamination. A new Australian Sewerage Acceptance Guideline is suggesting a pesticide discharge limit of 1 ppm. The third area of concern is pesticide residues in refined lanolin. This problem was discussed previously. The fourth area of concern is residual pesticide in scoured wool. Because of current and future plans for "eco-labeling" of all textiles, the level of pesticides in wool textiles will need to be zero. Proposed Interlaine (a European wool trade association) eco-labeling rules specify total organochlorine residues less than .2 ppm, organophosphates less than 2 ppm, and pyrethroids less than 3 ppm in **raw** wool in order to ensure no measurable pesticide in the scoured, dyed, and finished textile product (Shaw, 1996).

It appears obvious from published reports that if recommended chemicals are applied at the correct concentration and at the right time, no serious contamination of grease wool, scoured wool, or wool grease would occur. However, residual pesticides may create problems if applied at the wrong strength or just prior to shearing.

The current experiment was designed to determine residual levels of two commonly used insecticides applied at normal and 3 times the recommended levels 23 d before shearing a 12-mo wool clip. The latter condition was used as a "worst-case scenario."

Procedure

Thirty Rambouillet ewes having 11-mo fleeces were identified for this study. The ewes were maintained together on rangeland in the San Angelo area before and after treatment. These sheep had not been treated with any pesticides in the preceding year. Treatments were imposed on March 22, 1995, and consisted of the following. For control purposes, five ewes were not sprayed and another five were sprayed with water only. Two groups containing five sheep each were sprayed separately with recommended concentrations of malathion (.5%) and diazinon (.5%). Finally, two other groups of five ewes each were sprayed separately with three times the recommended concentrations of malathion (1.5%) and diazinon (1.5%). A high-pressure sprayer was used to ensure thorough penetration of the fleeces. Sheep were sprayed until fleeces were saturated. The 30 ewes were permitted to continue grazing together for 3 wk after which they were shorn. Individual fleeces were packaged separately and taken to the Wool and Mohair Research Lab. At least 200 g of ½-inch cores were removed from each fleece. Cores from each fleece within a group were

combined and blended prior to further analysis. This action negated statistical analyses but was necessary (for financial reasons). Representative samples of greasy cores (250 g each) from each of the six groups were analyzed for organophosphorus insecticides at Warren Analytical Laboratory. The 11 compounds included in the analysis were chlorpyrifos, disyston, ethion, malathion, pirimiphos-methyl, trithion, diazinon, ethyl parathion, fenitrothion, methyl parathion, and ronnel. In addition, samples of scoured wool and scouring liquor (1 liter of effluent from the first wash) representing each group were also analyzed for organophosphorus insecticides. The detection limits were .05 ppm for wool samples and .01 ppm for liquid samples. As a precaution against contamination (specifically, plasticizers in plastic bags), all samples were packaged in glass Mason jars. The ratio of greasy wool to scouring liquor in the first wash was 250 g : 6 L ≡ 1 : 24. The scouring operation was conducted quantitatively (ASTM, 1995) in order that clean yields could be calculated for each group of fleeces. An OFDA (IWTO, 1995) was used to determine the fiber diameter distribution of each group of scoured cores.

Results and Discussion

Grease Wool. Malathion was applied at rates of .5 and 1.5%, this being equivalent to 5,000 and 15,000 ppm to sheep having the fleece properties summarized in Table 1. After 3 wk, the amount of malathion remaining in the fleeces was 6.25 and 116 ppm, respectively (Table 2). During the same time frame, the concentrations of diazinon in the fleeces of sheep sprayed with this chemical diminished to 127 and 160 ppm, respectively. Diazinon degraded at a slower rate than malathion in this situation. It is obvious that some transfer of insecticides occurred among groups of sheep. Even the fleeces of the animals in the two control groups contained measurable amounts of both insecticides. This contamination probably occurred when the sheep returned to the flock soon after being sprayed and while they were still wet.

Table 1. Average values of fleece properties for the 6 treatment groups

Treatment	Lab scoured yield, %	Average fiber diameter, μm
Not sprayed	59.1	21.4
Water	60.7	20.8
.5% Malathion	61.9	21.2
1.5% Malathion	62.0	21.3
.5% Diazinon	61.0	20.1
1.5% Diazinon	66.3	21.2
Mean Values	61.8	21.0

Table 2. Insecticide concentrations in grease wool, scoured wool, and scouring liquor (effluent) emulsions

Treatment	Sample type[1]	Malathion, ppm[2]	Diazinon, ppm
Not sprayed	GW	.22	7.16
	SW	ND	ND
	EFF	ND	.26
Water	GW	.44	11.00
	SW	ND	.14
	EFF	ND	.20
.5% Malathion	GW	6.25	9.73
	SW	ND	.06
	EFF[3]	.03	.29
1.5% Malathion	GW[4]	116.00	11.30
	SW	ND	ND
	EFF	.11	.33
.5% Diazinon	GW[5]	.67	127
	SW	ND	.23
	EFF	ND	6.86
1.5 Diazinon	GW[5]	.09	160
	SW	ND	.83
	EFF	ND	11.56

[1]GW = grease wool, SW = scoured wool, EFF = scouring liquor (effluent) emulsion
[2]ND = none detected at a detection limit of .05 ppm for GW and SW and .01 ppm for EFF
[3]Also .03 ppm ethyl parathion and .02 ppm methyl parathion
[4]Also .05 ppm chlorpyrifos
[5]Also .10 ppm chlorpyrifos

Though the concentrations of insecticide had declined rapidly in the 3 wk after application, residual levels in the grease wool caused undesirable exposure to shearers and wool handlers.

Scoured wool. Malathion was not detectable in any of the scoured wool samples. If it was present, its concentration was less than .05 ppm. Very small amounts (.06 to .83 ppm) of diazinon were found in four of the six scoured wool samples. Thus, spraying these insecticides, even at this short time before shearing, did not result in retention of significant amounts of either insecticide in the scoured wool. These small amounts would certainly be further reduced in subsequent wet processing (washing, dyeing, and finishing).

Scouring liquor. Malathion was not detected in the scouring liquor of either of the control groups or the diazinon-sprayed groups. However, it was detected at very low levels (.03 and .11 ppm) in the scouring liquor of the malathion-sprayed fleeces. Diazinon was detected (.20 to 11.56 ppm) in the scouring liquor from all groups. These findings have serious consequences for scourers and refiners of wool grease because both insecticides would tend to concentrate in the fatty rather than the aqueous fractions.

Other pesticides. Three other pesticide residues were detected. In the case of the 1.5% malathion treatment, the methyl and ethyl parathion found in the effluent sample almost certainly emanated from the commercial-grade malathion. Similarly, chlorpyrifos found in the grease wool of both the diazinon treatments was possibly an impurity in this commercial grade product.

Conclusions

Late-season applications to sheep of organophosphorus insecticides that are known to degrade relatively quickly in the environment resulted in undesirable residual levels of insecticide in both grease wool and scouring liquor emulsions. Spraying sheep with insecticides a short time before shearing is therefore not recommended. The scouring process removed most of the residual insecticide leaving only very minute quantities in the scoured wool. Pesticide levels in wools produced overseas are currently a cause for concern (Anon., 1994, 1995). There is no evidence to suggest that any U.S.-produced wool contains excessively high levels of pesticides. Every effort should be made to maintain this situation.

Literature Cited

Anonymous. 1994. Bid to halve pesticide residues in export wool. The New Zealand Farmer, July 27: 7.

Anonymous. 1995. Pesticide levels will be reduced. Wool Record. 154, 3614:5.

ASI. 1988. Health Chapter. SID Sheep Production Handbook. American Sheep Industry Association, Englewood, CO:252.

ASTM. 1995. Standard test method D584 for wool content of raw wool - laboratory scale. Annual Book of ASTM Standards. 07.01:190. ASTM, Philadelphia.

Craddock, F. 1995. Texas Agricultural Extension Service. Personal communication.

Cunningham, W. 1994. Colorado State University. Personal communication.

Fuchs, T.W., C.E. Hoelscher, C.D. Patrick, J. Cocke, Jr., J.V. Robinson, and C.L. Cole. 1990. Suggestions for managing external parasites of Texas livestock and poultry. Texas Agric. Ext. Serv. B-1306.

IWTO. 1995. Test method 47-95. Measurement of the mean and distribution of fibre diameter of wool using an Optical Fibre Diameter Analyser (OFDA). Int. Wool Secretariat. Ilkley, UK.

Russell, I.M. 1990. Dermal transfer of pesticide residues from wool grease and lanolin: a method for hazard assessment. Proc. 8th Int. Wool Text. Res. Conf. Vol.III:165.

Russell, I.M. 1994. Pesticides in wool: downstream consequences. Wool Tech. Sheep Breed. 42, 4:344.

Russell, I.M., N.J. Campbell, P.D. Hanrahan, C.R. Nunn, and G.C. Smith. 1995. Reduction of pesticide residues on the Australian wool clip. Proc. 9th Int. Wool Text. Res. Conf.Vol. I:101.

Shaw, T. 1996. Draft 2. Proposed Interlaine eco-label criteria for wool apparel: rationale for criteria. Int. Wool Secretariat. Ilkley, UK.

Story, P.R. 1992. An investigation of wool scouring relative to new USP requirements for pesticide levels in lanolin. Communicated to Paul Rodgers, ASI, 12/31/1992.

How Different is Lamb from Other Meats? Sensory Evaluation of Pan-fried Ground Meat Patties by Consumers

Y.A. Ziprin and K.S. Rhee

ABSTRACT

Pan-fried lamb, beef and pork patties containing approximately 21% fat were evaluated by consumers (a large number of untrained sensory panelists) to determine if they could correctly identify the species and to document the probable basis of their identification. Of the 71 people who evaluated meat patty samples, 59, 49, and 32% correctly identified lamb, beef, and pork, respectively. Flavor intensity of lamb and pork patties did not have positive effects on their overall palatability, whereas flavor intensity of beef patties had positive effects. Lamb patties were rated most intense in flavor and lowest in overall palatability.

Introduction

Meat flavor is a major consideration in the selection of meat by consumers. Species-specific flavor notes in combination with a blend of general meaty notes common to all meats determine fresh cooked meat flavor (Brennand and Lindsay, 1992). It is believed that the limited consumption of lamb in the U.S. is partially due to its distinct flavor. However, to what extent consumers can indeed sensorially differentiate lamb from other meats has not been clearly documented. According to an early report (Howe and Barbella, 1937), beef and pork were identified correctly more often than lamb in blind tests, but no data were presented. Then in 1968, Wasserman and Talley reported that beef and lamb, compared to pork, were identified less often when lean ground roasts (baked meat loaves) were tested. However, opposite results were found when ground roasts containing fat were evaluated. In the study by Wasserman and Talley, the cooked samples were refrigerated overnight and brought to room temperature before serving. According to the authors, cold meat samples were identified with the same accuracy as warm meat samples. However, unless the cooked samples were stored anaerobically, as in vacuum packaging, overnight storage at refrigeration temperature could cause lipid oxidation and that in turn could potentially affect identification of the species. Reid et al. (1993) reported that mutton flavor was more intense when cooked mutton adipose tissue was stored anaerobically than when stored aerobically (under high oxygen condition), whereas lipid oxidation was greater in aerobically stored samples. They suggested that compounds responsible for mutton odor could undergo a greater degree of degradation in the presence of oxygen and that lipid oxidation products could conceivably mask the mutton flavor. The objective of this study was to document the ability of consumers to differentiate lamb from other meats (beef and pork) and the acceptance levels of these meats, when presented as pan-fried ground meat patties.

Experimental Procedure

Ground meat patties with a target fat level of 20% were prepared from fresh lamb legs and shoulders, beef chucks, or pork boston shoulders. Patties (1/4 lb, 3/4-in. thick) were crust-frozen at -4 °F, vacuum packaged, and stored at -4 °F until used for cooking. The frozen patties were thawed overnight at 39 °F and pan-fried in a preheated household skillet at 325 °F to a final internal temperature of 160 °F. The cooked patties were crust-frozen, vacuum packaged, and held frozen for 4 d until used for sensory evaluation. Precooked patties were reheated in a microwave oven (700 watt) without prior thawing. Each patty was sliced into six wedges for serving and placed in warm plates, loosely covered with aluminum foil and kept warm in a 120 °F oven for 5 min or less before serving. Sensory panelists (71 people) were undergraduate and graduate students, faculty, and staff at Texas A&M University. Each panelist evaluated two serving sets of the three meat types or a total of six samples. The serving order for the three meat types within each serving set was preset and used for all the panelists. The serving orders were pork, lamb, and beef in the first set and beef, lamb, and pork for the second set. In addition to species identification, all samples were evaluated for the following sensory attributes: flavor intensity (1 = extremely weak; 9 = extremely intense), juiciness (1 = extremely dry; 9 extremely juicy), tenderness (1 = extremely tough; 9 = extremely tender), and overall palatability (1 = dislike extremely; 9 = like extremely). Five raw or cooked patties from each species were homogenized for fat and moisture analyses. Moisture was determined using the AOAC (1990) oven-drying method, and fat content was gravimetrically determined on lipid extracts prepared by the procedure of Folch *et al.* (1957).

The SAS (1990) program was used for all data analyses. Data were first analyzed by the Frequency Procedure for the number/percentage of panelists who correctly identified the species of the samples. In

addition, the Frequency Procedure was used to compute chi-square tests and measures of association between serving order and correct/incorrect species identification. Computations were done with all three species included and with just beef and lamb. For those samples whose species were correctly identified, their sensory attribute scores were analyzed by the General Linear Models Procedure and mean separation by the Student-Newman-Keuls test. The Correlation Procedure was used to determine relationships between sensory attributes.

Results and Discussion

For the first serving set, 68% of panelists correctly identified lamb whereas 76 and 39% were correct on beef and pork, respectively (Table 1). The low percentage of correct responses for the pork might be partially due to the fact that it was the first sample served. For the second serving set, 80% of consumer panelists made correct identification of lamb as well as

Table 1. Species identification by a consumer sensory panel

	Panelists who correctly identified species	
Sample	Number	% of all panelists (n = 71)
First serving		
Beef	54	76.1
Lamb	48	67.6
Pork	28	39.4
Second serving		
Beef	44	62.0
Lamb	57	80.3
Pork	57	80.3
Both servings		
Beef	35	49.3
Lamb	42	59.2
Pork	23	32.4

pork, and only 62% for beef. Less than 60% correctly identified both servings of any of the species, with the highest correct identification for lamb (59%). Since meat patties were pan-fried for sensory evaluation, the browned/fried flavor resulting from the cooking method might have had some masking effect on species-related flavors. Note that species identification was not influenced by fat or moisture levels of samples served because cooked patty fat content (21.6 to 23.4%) and moisture (49.3 to 50.6%) were not significantly different ($P > .05$) among the species. Presumably, lamb could have been even more distinguishable if the meat patties had been cooked by a preparation method that results in less browned/fried flavors than pan-frying.

When species identification responses were analyzed to determine the degree of association between sample presentation order and response (correct or incorrect identification), contingency coefficients were all low. Contingency coefficients were 0.25 with all three species included and 0.15 without pork, indicating that the serving order-response association was weak even with all three species included and still weaker when responses on only beef and lamb were used in the analysis.

Sensory scores of those samples whose species were correctly identified indicated that panelists perceived lamb patty samples to have the highest flavor intensity (mean score, 7.1; about "moderately intense"), followed by pork samples (6.1; about "slightly intense") and beef samples (4.9; close to "neither intense nor weak") (Table 2). They also rated lamb and pork samples as juicier and more tender than

Table 2. Sensory attribute ratings for beef, lamb, and pork samples correctly identified

	Samples correctly identified [d]		
Attribute	Beef	Lamb	Pork
Flavor intensity	4.9[c]	7.1[a]	6.1[b]
Juiciness	3.9[c]	4.8[b]	5.3[a]
Tenderness	5.5[b]	6.0[a]	6.2[a]
Overall palatability	5.1[a]	4.4[b]	5.5[a]

[a-c]Means within the same row which are followed by the same superscript letters are not different ($P > 0.05$).

beef samples. Overall palatability scores were close to "dislike slightly" for lamb patty samples and between "neither like nor dislike" and "like slightly" for beef and pork samples. Panelists' lower overall palatability scores for lamb seemed to be due to its intense (species) flavor, because juiciness and tenderness ratings for lamb samples were as good as, or better than, those of the other two species samples. Correlation data (Table 3) on correctly identified samples indicated that flavor intensity of lamb patties indeed had a negative effect (or did not have a positive effect) on overall palatability whereas the opposite was true for beef patties. Flavor intensity of pork patties had neither positive nor negative effects on overall palatability, according to their correlation coefficients.

Conclusions

This study has documented that a majority of people can differentiate lamb from beef and pork in blind taste tests and that those who can differentiate species, perceive the lamb (species) flavor strong and may dislike lamb. Thus, flavor modification or reduction of species-related flavor would be an important consideration in developing value-added products from sheep meat that are targeted toward the population that does not currently like lamb flavor.

Acknowledgment

The paper reports research conducted by the Texas Agricultural Experiment Station, The Texas A&M University System. This study was partially supported by the Texas Food and Fibers Commission, Dallas.

Literature Cited

AOAC. 1990. Official Methods of Analysis. (15th Ed.) Association of Official Analytical Chemists. Washington. D.C.

Brennand. C.P., and R.C. Lindsay. 1992. Influence of cooking on concentrations of Species-related flavor compounds in mutton. Lebensm.-Wiss. Technol. 25:357-364.

Folch, J., M.Lees, and G.H. Sloane-Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497-509.

Howe, P.E., and N.G. Barbella. 1937. The flavor of meat and meat products. Food Res. 2:197.

Reid, D.H., O.A. Young, and T.J. Braggins. 1993. The effects of antioxidative treatments on mutton flavour/odour intensity and species flavour differentiation. Meat Sci. 35:171-182.

SAS. 1990. SAS User's Guide: Statistics, Version 6 Ed. SAS Institute, Inc., Cary, N.C.

Wasserman, A.E., and F. Talley. 1968. Organoleptic identification of roasted beef, veal, lamb and pork as affected by fat. J. Food Sci. 33:219-223.

Table 3. Correlations between sensory attributes for beef, lamb and pork samples correctly identified

	Correlation coefficient* with samples correctly identified		
	Beef	Lamb	Pork
First serving sata[a]			
Flavor vs overall palatability	0.65	0.33	0.06[ns]
Juiciness vs overall palatability	0.54	0.11[ns]	0.64
Tenderness vs overall palatability	0.61	0.07[ns]	0.55
Second serving data[b]			
Flavor vs overall palatability	0.60	-0.003[ns]	0.16[ns]
Juiciness vs overall palatability	0.41	0.49	0.62
Tenderness vs overall palatability	0.49	0.48	0.45
Combined data[c]			
Flavor vs overall palatability	0.63	-0.11[ns]	0.13[ns]
Juiciness vs overall palatability	0.57	0.32	0.63
Tenderness vs overall palatability	0.56	0.26	0.47

[a]n = 54 for beef; n = 48 for lamb; n = 28 for pork.
[b]n = 44 for beef; n = 57 for lamb; n = 57 for pork.
[c]n = 99 for beef; n = 105 for lamb; n = 85 for pork.
[ns]Not significant (P > .05).
*The correlation coefficient is a measure of the mutual relationship between two variables, ranging from -1 (perfect negative correlation) to +1 (perfect positive correlation). A positive (plus) correlation coefficient indicates that as the value of one variable increases, so does the value of the other variable, whereas a negative (minus) coefficient indicates that as the value of one increases, the value of the other decreases.

Effect of Breed-type and Feeding Regimen on Goat Carcass Characteristics

J.S. Oman, D.F. Waldron, D.B. Griffin, and J.W. Savell

ABSTRACT

Meat-type (Boer x Spanish, Spanish) goats from two feeding regimens (feedlot, range) were slaughtered, and live and carcass weights were obtained. At 24 h postmortem, various yield and quality measurements were taken. One side from each carcass was fabricated into major wholesale cuts for dissection into major carcass components. Feedlot goats had heavier ($P < .05$) live and carcass weights, higher ($P < .05$) fat and lean and lower bone dissectable carcass portions when compared to range goats. Boer x Spanish goats had significantly greater live weights, carcass weights, carcass conformation scores and leg circumference scores when compared to Spanish goats of similar age. There were no significant differences in carcass traits between Boer x Spanish and Spanish goats when data were adjusted for live weight.

Introduction

A rising demand for goat meat in Texas and the U.S. has resulted from increased ethnic diversity in the U.S. In the last decade, immigration into the U.S. has averaged 61,150 persons each month; many of these immigrants are goat meat consumers (Pinkerton et al., 1994). USDA slaughter numbers reflect the growing demand for goat meat. Approximately 60,000 meat goats were slaughtered at USDA-inspected plants in 1981; in 1990, approximately 200,000 goats were slaughtered in USDA-inspected plants (NASS, 1991).

Goat production in Texas and the U.S. historically has been a low-labor enterprise with little emphasis on productivity and management practices. Because of their ability to utilize marginal range resources, goats in Texas have been used primarily for brush control. Variations exist in animal availability, breed type, feeding regimen, body weights, condition at slaughter and carcass characteristics.

The majority of the meat-type goats in the U.S. are Spanish goats. The term "Spanish" is used to describe common, meat-type goats and to distinguish them from dairy- and fiber-type goats; technically, " Spanish" is not a breed (Paschal, 1992). Dairy- and fiber-type goats are also a source of meat. The Boer breed was developed in South Africa for the purpose of meat production. This breed is known for its larger frame size, increased muscularity and characteristic white body and brown or red-colored head. Boer goats were imported into the U.S. in April 1993. According to a simulation study reported by Blackburn (1995), Boer goats should produce more saleable weight per doe than Spanish goats when forage conditions are not limited; however, under less than optimal conditions, they are not more productive.

The effect of breed-type and diet on goat carcass characteristics has been investigated in only a limited number of studies. The objectives of this study were to determine the effects of breed-type and feeding regimen on carcass characteristics of meat-type goats.

Materials and Methods

This study included Boer x Spanish and Spanish kids obtained from the Texas Agricultural Experiment Station (TAES) at San Angelo, Texas. All animals were intact males and from the spring 1994 kidding season. The Boer x Spanish and Spanish kids were a subset of those used in a breed comparison trial (Waldron et al., 1996). The kids in this study were chosen to be representative of each of the sires. Boer x Spanish, $n = 24$ and Spanish, $n = 24$ kids were assigned randomly to either a feedlot ($n = 12$ for each breed-type) or a range ($n = 12$ for each breed-type) treatment. Kids assigned to the feedlot treatment were fed either a 12.5 or 15% crude protein diet. Range kids were turned out on rangeland consisting of multiple species of native grasses and forbs; no supplemental feed was given, and rainfall was atypically low.

After 112 d on either the feedlot or pasture treatment, animals were slaughtered at the Rosenthal Meat Science and Technology Center on the Texas A&M University campus. All kids were approximately 9 mo of age at the time of slaughter. Live weights and warm carcass weights were collected. Carcasses were chilled at 2 °C, and at approximately 24 h postmortem, the following measurements were taken: longissimus muscle area at the 12th rib; actual and adjusted (visually adjusted for variations in fat thickness over the leg, loin, rack, and shoulder) 12th rib fat thickness; body wall thickness (5.1 cm from the edge of the longissimus dorsi); leg circumference (across the stifle area of the leg, encompassing both legs); and carcass length (measured from the point of the hock to the point of the shoulder). Scores for marbling, flank streaking, maturity, color, and buckiness (based on a 5-point scale where 1 = no buckiness and 5 = extremely bucky) also were assigned by Texas Agricultural Experiment Station personnel to each carcass.

Because no official grading standards designed specifically for U.S. goat carcasses exist, number scores

and general descriptions were assigned for carcass conformation based on muscle shape and thickness of the leg, loin, rack, and shoulder. A scale was developed by selecting carcasses representative of eight conformation types given even-numbered scores 0 to 14. Animals falling between the categories were assigned odd-numbered scores, resulting in a 15-point scale where 1 = very thin and angular and 15 = very thick and bulging. Figure 1 illustrates animals representative of conformation scores 2, 4, 6, 8, 10, and 12.

One side from each carcass was dissected into knife separable components of subcutaneous fat, intermuscular fat, internal fat, lean and bone to determine physical composition. Analysis followed a 2 X 2 factorial arrangement with breed-type (Boer x Spanish and Spanish) and feeding regimen (feedlot and range) as the main effects. Least squares means were generated, and all data were analyzed using SAS PROC GLM (1991).

Results and Discussion

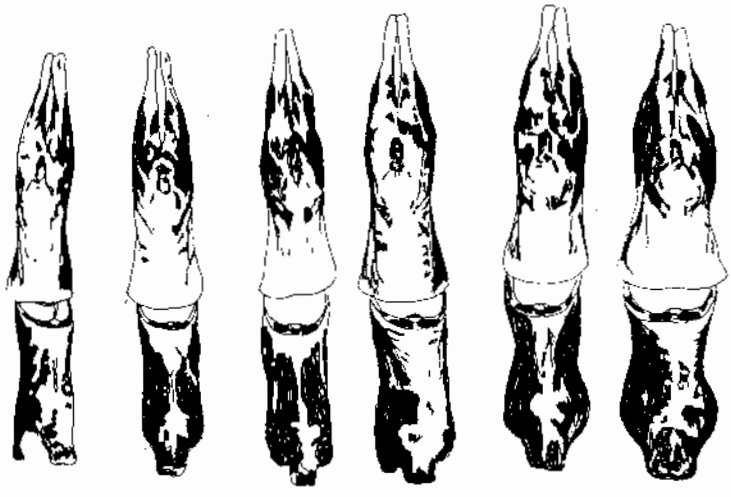
There was a significant interaction between breed and feeding regimen only for actual and adjusted fat thickness (Figure 2). Feedlot Boer x Spanish goat carcasses possessed higher ($P < .05$) actual and adjusted fat thicknesses than did feedlot Spanish goat carcasses. Additionally, feedlot goat carcasses had higher actual and adjusted fat thicknesses than did range goat carcasses. Mean live weights, carcass weights, and carcass measurements for meat-type goats within breed-type are reported in Table 1. Boer x Spanish goats possessed heavier ($P < .05$) live and carcass weights, higher ($P < .05$) carcass conformation scores and larger ($P < .05$) leg circumferences than did Spanish goats. All other carcass

Table 1. Mean carcass yield and quality measurements for meat-type goats within breed-type

Item	Boer x Spanish	Spanish
Live wt, lb	64.55[e]	57.13[f]
Warm carcass wt, lb	34.89[e]	30.54[f]
Longissimus muscle area, in^2	1.50	1.34
Body wall thickness, in	.45	.38
Carcass conformation score[a]	7.33[e]	5.08[f]
Carcass length, in	39.06	38.35
Leg circumference, in	19.47[e]	18.71[f]
Lean maturity score[b]	1.39	1.43
Skeletal maturity score[b]	1.56	1.57
Marbling score[c]	2.53	2.43
Live wt, lb	64.55[e]	57.13[f]
Flank streaking score[c]	2.82	2.59
Buckiness score[d]	2.96	2.71

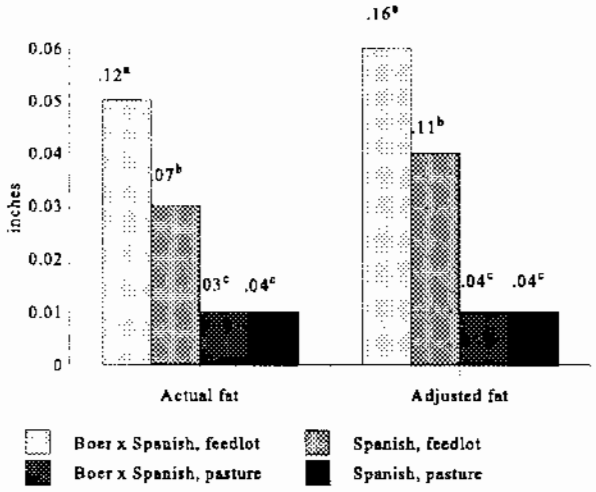
[a]Means based on a 15-point descriptive scale (1.0 = very angular, narrow and thin; 15.0 = extremely thick and bulging).
[b]Means based on USDA skeletal and lean maturity scores for lamb [1.00 = A^{00} (0 to14 mo of age; break joint present); 2.00=B^{00} (over 14 mo of age; break joint not present)].
[c]Means based on USDA marbling and flank streaking scores (1.00 = Practically devoid^{00}; 3.00 = Slight^{00}; 5.00 = Modest^{00}).
[d]Means based on a 5-point scale (1.0 = no buckiness; 5.0 = extreme buckiness).
[e,f]Means in the same row with different superscripts are different ($P < .05$).

Figure 1. Conformation score scale.



No. 2 No. 4 No. 6 No. 8 No. 10 No. 12

Figure 2. Mean and actual adjusted fat thickness in inches over the 12th rib for meat-type goats



[abc]Means with different superscript letters for each set of measurements are different ($P < .05$).

measurements were not different ($P > .05$). Diet had a significant effect on live and carcass weights and carcass measurements (Table 2). Feedlot goats possessed heavier ($P < .05$) live and carcass weights, larger ($P < .05$) longissimus muscle areas, higher ($P < .05$) body wall thicknesses, carcass conformation scores, carcass lengths, leg circumferences, skeletal maturity scores, marbling scores, flank streaking scores, and buckiness scores. Lean maturity scores were not different ($P > .05$). When the carcass measurements were adjusted for live weight there were no significant differences between Boer x Spanish and Spanish goats.

Mean percentages of carcass components within breed-type and feeding regimen are reported in Table 3. Feedlot Boer x Spanish and Spanish goat carcasses had a higher ($P < .05$) percentage of lean for the side than did range Spanish goat carcasses; however, feedlot Spanish goat carcasses were not different ($P > .05$) from range Boer x Spanish goat carcasses for lean percentage. Feedlot goat carcasses possessed higher ($P < .05$) fat percentages and lower ($P < .05$) bone percentages when compared to range goat carcasses. This trend was generally observed for most major wholesale cuts.

Diet has been found to also play a significant role on carcass characteristics in other species. Tatum et al. (1989) reported that lambs fed in a feedlot produced fatter carcasses than lambs fed limited or no grain. Several studies have verified this theory in beef cattle as well (Bowling et al., 1977; Schroeder et al., 1980; Burson et al., 1980).

Table 2. Mean carcass yield and quality measurements for meat-type goats within feeding regimen

Item	Feedlot	Range
Live wt, lb	78.87[e]	42.83[f]
Warm carcass wt, lb	44.81[e]	20.61[f]
Longissimus muscle area, in^2	1.86[e]	.98[f]
Body wall thickness, in	.61[e]	.23[f]
Carcass conformation score[a]	9.86[e]	2.54[f]
Carcass length , in	41.59[e]	35.82[f]
Leg circumference, in	21.15[e]	17.03[f]
Lean maturity score[b]	1.39	1.43
Skeletal maturity score[b]	1.44[f]	1.68[e]
Marbling score[c]	3.20[e]	1.75[f]
Flank streaking score[c]	3.51[e]	1.89[f]
Buckiness score[d]	4.21[e]	1.46[f]

[a]Means based on a 15-point descriptive scale (1.0 = very angular, narrow and thin; 15.0 = extremely thick and bulging).

[b]Means based on USDA skeletal and lean maturity scores for lamb [1.00 = A^{00} (0-14 mo of age; break joint present); 2.00 = B^{00} (over 14 mo of age; break joint not present)].

[c]Means based on USDA marbling and flank streaking scores (1.00 = Practically $Devoid^{00}$; 3.00 = $Slight^{00}$; 5.00 = $Modest^{00}$).

[d]Means based on a 5-point scale (1.0 = no buckiness; 5.0 = extremely bucky).

[ef]Means in the same row with different superscripts are different ($P < .05$).

Table 3. Mean percentage of carcass components for meat-type goats within breed-type and feeding regimen

		Boer x Spanish		Spanish	
Cut	Component	Feedlot	Range	Feedlot	Range
Side[a]	Lean (%)	57.79^{b}	55.78^{bc}	57.61^{b}	55.28^{c}
	Bone (%)	26.50^{c}	36.89^{b}	27.58^{c}	36.48^{b}
	Fat (%)	15.71^{b}	7.34^{c}	13.40^{b}	8.24^{c}
Shoulder	Lean (%)	61.43^{bc}	59.59^{c}	63.30^{b}	60.85^{bc}
	Bone (%)	21.57^{c}	31.93^{b}	22.17^{c}	29.42^{b}
	Fat (%)	16.88^{b}	8.16^{c}	14.40^{b}	9.45^{c}
Rack	Lean (%)	54.16^{bc}	50.96^{d}	56.16^{b}	52.19^{cd}
	Bone (%)	29.43^{c}	43.97^{b}	30.61^{c}	40.38^{b}
	Fat (%)	16.41^{b}	5.07^{c}	13.24^{b}	7.43^{c}
Shortloin	Lean (%)	56.54^{b}	50.49^{c}	52.83^{bc}	50.34^{c}
	Bone (%)	24.40^{c}	42.68^{b}	25.27^{c}	39.47^{b}
	Fat (%)	19.06^{b}	6.83^{c}	21.89^{b}	10.19^{c}
Sirloin	Lean (%)	57.17	54.36	56.41	54.18
	Bone (%)	21.02^{c}	35.90^{b}	25.34^{c}	34.41^{b}
	Fat (%)	21.81^{b}	9.74^{c}	18.25^{b}	11.41^{c}
Leg	Lean (%)	62.23^{b}	59.56^{c}	62.52^{b}	59.05^{c}
	Bone (%)	29.54^{c}	35.47^{b}	31.01^{c}	35.90^{b}
	Fat (%)	8.23^{b}	4.97^{d}	6.74^{c}	5.05^{d}

[a]Side includes major wholesale cuts plus neck, shank, breast, plate and flank.
[bcd]Means in the same row without a common superscript are different ($P < .05$).

Implications

Feeding goats results in heavier live and carcass weights, and heavier muscled, fatter carcasses. Cross-breeding using Boer influence results in heavier live and carcass weights, higher conformation scores, and larger leg circumferences when goats are compared at the same age. The Boer x Spanish goats were not significantly different from Spanish goats for any carcass traits when adjusted to a common live weight. This suggests that the advantage of the Boer x Spanish kids is in the greater growth rate. There is a need for standardized grades to facilitate marketing of the various sizes and types of goats currently being produced. The carcass conformation scale developed for this study could assist in developing some type of grading system. Because much of the goat meat consumed today is by ethnic groups with different preferences in terms of age, weight, and quality, future research should focus on market development and de-termining the demand for various types and sizes of goats.

Literature Cited

Blackburn, H.D. 1995. Comparison of performance of Boer and Spanish goats in two U.S. locations. J. Anim. Sci. 73:309.

Bowling, R.A., G.C. Smith, Z.L. Carpenter, T.R. Dutson, and W.M. Oliver. 1977. Comparison of forage-finished and grain-finished beef carcasses. J. Anim. Sci. 45:209.

Burson, D.E., M.C. Hunt, D.M. Allen, C.L. Kastner, and D.H. Kropf. 1980. Diet energy density and time on feed effects on beef longissimus palatability. J. Anim. Sci. 51:875.

NASS. 1991. National Agricultural Statistical Service. USDA. Washington, DC. January 1, 1994.

Paschal, J.C. 1992. Basic genetics, selection and breeding of the meat goat. Proceedings of the International Conference on Meat Goat Production, Management and Marketing. P. 49.

Pinkerton, F., N. Escobar, L. Harwell, and W. Drinkwater. 1994. A survey of prevalent production and marketing practices in meat goats of southern origin. Southern Rural Development Center. Mississippi State, MS. p. 10.

SAS. 1991. SAS User's Guide: Statistics (4th Ed.). SAS Institute, Inc., Cary, NC.

Schroeder, J.W., D.A. Cramer, R.A. Bowling, and C.W. Cook. 1980. Palatability, shelf-life and chemical differences between forage- and grain-finished beef. J. Anim. Sci. 50:852.

Tatum, J.D., J.W. Savell, H.R. Cross, and J.G. Butler. 1989. A national survey of lamb carcass cutability traits. SID Res. J. 5(1):23.

Waldron, D.F., T.D. Willingham, P.V. Thompson, J.E. Huston. 1996. Growth rate and feed efficiency of Boer x Spanish compared to Spanish goats. Texas Agric. Exp. Sta. Prog. Rep. CPR-5257.

Carcass Characteristics and Retail Shelf-life of Meat- and Fiber-type Goats

J.S. Oman, D.F. Waldron, D.B. Griffin, and J.W. Savell

ABSTRACT

Meat-type (Boer x Spanish, Spanish) and fiber-type (Spanish x Angora, Angora) goats were weighed, then slaughtered, and carcass weights were obtained. At 24 h postmortem, various yield and quality measurements were taken. One side from each carcass was fabricated into major wholesale cuts for dissection into major carcass components. Rib chops from the opposite side were fabricated, packaged, and displayed in a retail case. Trained panelists evaluated the rib chops for lean color, surface discoloration, and overall appearance for day 0, 1, 2, 3, and 4; packages were opened and analyzed for off-odor on day 4. Generally, the fiber-type goats possessed higher measures of fat and lower measures of lean when compared to the meat-type goats. It is important to note that the Angora carcasses possessed a higher ($P < .05$) percentage of intermuscular fat. Differences also were observed between crossbreeds (Spanish x Angora and Boer x Spanish) and purebreeds (Angora and Spanish) in that crossbreeds produced heavier ($P < .05$) carcass and offal weights. Shelf-life was not affected by breed-type.

Introduction

Two events in 1993 will influence U.S. goat production in the future: 1) the importation of Boer goats into the U.S. and 2) the repeal of the National Wool Act and the subsequent phase-out of wool and mohair incentive payments to producers. The latter event has already had a major impact on Angora goat producers--especially in Texas--where 86% of the nation's Angora goats and 91% of the nation's mohair are produced (NASS, 1994). According to Jones and Wyse (1993), this policy decision could result in a loss of 3,000 jobs and a decline in personal income of $75 million in a 41 county region of Texas. Producers need alternative uses for the traditionally fiber-producing animals. Because selection in Angora goat breeding has historically been based primarily on fiber quantity and quality, relatively little emphasis was placed on meat-type traits. Boer goats, which are native to South Africa, have a high meat yielding potential (Van Niekerk and Casey, 1988). However, the influence of Boers in crossbreeding systems has not been studied. With the phase-out and future elimination of the wool and mohair incentive, some Angora goat producers are looking for an alternative outlet for their stock. Crossbreeding with meat-type Spanish, Boer or Boer cross goats could be a feasible management practice.

In conversations with producers and retailers, meat from Angora goats is often discriminated against because it is believed to have a shorter shelf-life than meat from other breeds. However, there has been no published research that supports this idea. Much of the research in the area of meat goats has focused on breeding, reproduction, productivity, and other live-animal aspects. Only limited research has focused on the final product of meat goats. The objectives of this study were to determine the effects of breed type on carcass characteristics and retail shelf-life of meat- and fiber-type goats.

Materials and Methods

Meat- (Boer x Spanish, n = 12 and Spanish, n = 12) and fiber-type (Spanish x Angora, n = 6 and Angora, n = 6) kids were obtained from the Texas Agricultural Experiment Station (TAES) at San Angelo, Texas. All goats were intact males from the same kidding season and were fed either a 12.5 or 15% crude protein diet. The Boer x Spanish and Spanish kids were a subset of those used in a breed comparison trial (Waldron et al., 1996). The kids in this study were chosen to be representative of each of the sires. After 112 d on feed, kids were slaughtered at the Rosenthal Meat Science and Technology Center on the Texas A&M University campus. All kids were approximately 9 mo of age at the time of slaughter. Live weights and warm carcass weights were collected.

Carcasses were chilled at 2 °C, and at approximately 24 h postmortem, the following measurements were taken: longissimus muscle area at the 12th rib; actual and adjusted (visually adjusted for variations in fat thickness over the leg, loin, rack, and shoulder) 12th rib fat thickness; body wall thickness (5.1 cm from the edge of the longissimus dorsi); leg circumference (across the stifle area of the leg, encompassing both legs); and carcass length (measured from the point of the hock to the point of the shoulder). Scores for marbling, flank streaking, maturity, color, and buckiness (based on a 5-point scale where 1 = no buckiness and 5 = extreme buckiness) also were assigned by Texas Agricultural Experiment Station personnel to each carcass. Because no official grading standards designed specifically for U.S.

goat carcasses exist, number scores and general descriptions were assigned for carcass conformation based on muscle shape and thickness of the leg, loin, rack, and shoulder (Oman et al., 1996).

At approximately 48 h postmortem, carcasses were fabricated. One side from each carcass was dissected into knife separable components of subcutaneous fat, intermuscular fat, internal fat, lean, and bone to determine physical composition. The rack from the opposite side of each carcass was fabricated into six .75 in. thick chops. Two sequential chops were placed on a plastic foam tray and packaged with oxygen permeable overwrap film. Three packages of rib chops from each carcass were placed in an open-air retail case simulating retail conditions in a meat market. Packages were placed randomly in the case to allow for even distribution and to provide a rotational effect (to account for variations in temperature and light throughout the retail case). Texas Agricultural Experiment Station personnel analyzed the chops on days 0, 1, 2, 3, and 4 for lean color, surface discoloration, and overall appearance. Because no scale for goat lean color exists, a scale for lean color was developed prior to the study based on variations from the lean color scale for lamb set forth by Wanstedt (1982) (Table 1). Surface discoloration and overall appearance scales also followed those utilized by Wanstedt (1982). On day 4, each package was opened and analyzed for off-odor by Texas Agricultural Experiment Station personnel (Wanstedt, 1982).

Table 1. Scoring system for goat lean color

Description	Score
Bright, youthful reddish-pink	15
Moderately bright red	13
Cherry red	11
Slightly dark red	9
Moderately dark red	7
Dark red or brown	5
Very dark brown	3
Extremely dark brown	1

Analysis of data utilized breed as the main effect; color data for the retail shelf-life study were blocked by day and by panelist and odor data were blocked by panelist. All data were analyzed using SAS PROC GLM (1991).

Results and Discussion

Least squares means of carcass measurements are reported in Table 2. Live weights for Boer x Spanish and Spanish x Angora goats were not different ($P > .05$), and live weights for Spanish x Angora goats and Spanish goats were not different; Angora goats had lower ($P < .05$) live weights than all other breed-types involved in the study. This trend also was observed for carcass weights. Boer x Spanish, Spanish and Spanish x Angora goat carcasses possessed larger ($P < .05$) mean longissimus muscle area than did Angora goat carcasses. Carcasses from Spanish goats had a lower ($P < .05$) mean 12th rib fat thickness than all other breed-types. Fiber-type goats possessed carcasses with higher ($P < .05$) adjusted fat thicknesses than did meat-type goats.

Table 2. Least squares means of carcass yield and quality measurements for meat- and fiber-type goats

Carcass measurement	Boer x Spanish	Spanish	Spanish x Angora	Angora
Live wt, lb	84.07[e]	73.83[f]	80.33[ef]	61.67[g]
Warm carcass wt, lb	47.84[e]	41.89[f]	44.30[ef]	32.00[g]
Longissimus muscle area, in^2	1.94[e]	1.78[e]	1.78[e]	1.44[f]
Fat thickness, 12th rib, in	.05[e]	.03[f]	.05[e]	.05[e]
Adjusted fat thickness, in	.06[ef]	.04[f]	.09[e]	.09[e]
Carcass conformation score[a]	11.42[e]	8.33[f]	10.67[ef]	9.00[ef]
Carcass length, in	42.10[e]	41.08[e]	40.37[f]	37.00[g]
Leg circumference, in	21.60[e]	20.69[ef]	20.96[e]	18.79[f]
Lean maturity score[b]	1.42	1.45	1.88	1.37
Skeletal maturity score[b]	1.42	1.47	1.52	1.53
Marbling[c]	3.35[fg]	3.06[g]	4.12[ef]	4.13[e]
Flank streaking[c]	3.63[fg]	3.40[g]	4.31[e]	4.15[ef]
Buckiness score[d]	4.33[e]	4.08[ef]	4.83[e]	3.17[f]

[a]Means based on a 15-point descriptive scale (1.0 = very angular, narrow and thin; 15.0 = extremely thick and bulging).
[b]Means based on USDA skeletal and lean maturity scores for lamb [1.00 = A^{00} (0 to 14 mo of age; break joint present); 2.00 = B^{00} (over 14 mo of age; break joint not present)].
[c]Means based on USDA marbling and flank streaking scores (1.00 = Practically devoid^{00}; 3.00 = Slight^{00}; 5.00 = Modest^{00}).
[d]Means based on a 5-point scale (1.0 = no buckiness; 5.0 = extreme buckiness).
[efg]Means in the same row with different superscripts are different ($P < .05$).

Carcasses from Boer x Spanish goats had higher ($P < .05$) carcass conformation scores than carcasses from Spanish goats; carcasses from fiber-type goats had conformation scores that were not different ($P > .05$) from carcasses from meat-type goats.Meat-type goats possessed longer ($P < .05$) carcasses than carcasses from fiber-type goats. Carcasses from Angora goats had smaller ($P < .05$) leg circumferences than all other breed-types. No differences ($P > .05$) were observed among breed types for skeletal and lean maturity. Angora carcasses had higher ($P < .05$) marbling scores than meat-type carcasses, but were not different ($P > .05$) from Spanish x Angora carcasses. Spanish x Angora carcasses had higher ($P < .05$) flank streaking scores

than meat-type carcasses, but were not different (P > .05) from Angora carcasses. Angora goat carcasses had lower (P < .05) buckiness scores than did crossbred goat carcasses but were not different (P > .05) from Spanish goat carcasses. It should be noted that for all measurements except live weight and warm carcass weight, differences can be accounted for by differences in live weight or warm carcass weight.

Least squares means of percentage of carcass components are reported in Table 3. Meat-type goats possessed higher (P < .05) percentages of lean and lower (P < .05) percentages of fat for the side than did fiber-type goats. However, Spanish x Angora goat carcasses tended to not be different (P > .05) from meat-type goats for percentage of lean for the shoulder, rack, shortloin, sirloin, and leg. In general, percentage of bone was not different (P > .05) among breed-types. In a separate analysis of intermuscular fat, Angora goat carcasses possessed a higher (P < .05) percentage of intermuscular fat (as a percentage of side weight) when compared to all other breed-types. Boer x Spanish goats and Spanish goats were not different (P > .05; Figure 1).

Table 3. Mean percentage of carcass components for feedlot meat- and fiber-type goats

Cut	Component	Boer x Spanish	Spanish	Spanish x Angora	Angora
Side[a]	Lean %	57.79^{b}	57.61^{b}	55.12^{c}	51.57^{d}
	Bone %	26.50	27.58	25.61	25.81
	Fat %	15.71^{c}	13.40^{d}	19.27^{b}	22.62^{b}
Shoulder	Lean %	61.42^{bc}	63.30^{c}	58.80^{b}	54.46^{d}
	Bone %	21.57	22.17	22.13	21.98
	Fat %	16.88^{cd}	14.40^{d}	18.96^{c}	23.32^{b}
Rack	Lean %	54.16^{bc}	56.16^{b}	51.31^{cd}	46.72^{d}
	Bone %	29.43^{b}	30.61^{b}	27.40^{bc}	25.27^{c}
	Fat %	16.41^{cd}	13.24^{d}	21.30^{c}	28.00^{b}
Shortloin	Lean %	56.54^{b}	52.83^{b}	53.80^{b}	46.15^{c}
	Bone %	24.40	25.27	25.23	25.87
	Fat %	19.06^{c}	21.89^{c}	20.97^{c}	28.00^{b}
Sirloin	Lean %	57.16^{b}	56.41^{bc}	55.09^{bc}	50.61^{c}
	Bone %	21.02	25.34	21.73	22.29
	Fat %	21.81^{bc}	18.25^{c}	23.18^{bc}	27.10^{b}
Leg	Lean %	62.23^{b}	62.25^{b}	60.93^{b}	58.61^{c}
	Bone %	29.54^{bc}	31.01^{b}	28.95^{c}	29.54^{bc}
	Fat %	8.23^{cd}	6.74^{d}	10.12^{bc}	11.84^{b}

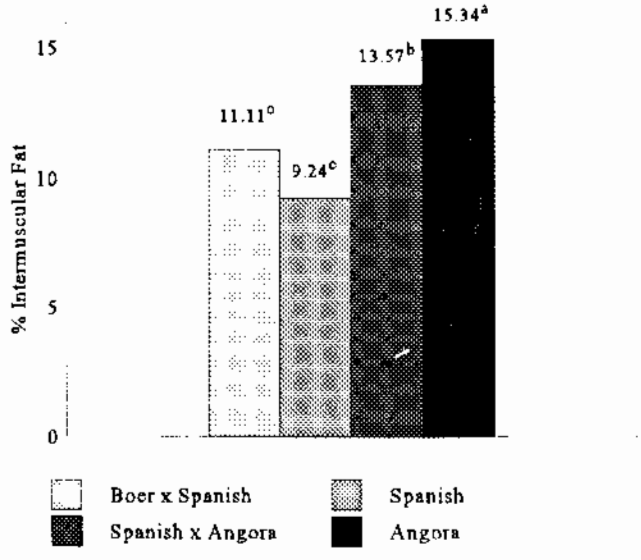
[a]Side includes major wholesale cuts plus neck, breast, plate and flank.
[bcd]Means in the same row with different superscripts differ (P < .05).

For the retail shelf-life phase of this study, interaction of breed by day was not significant for lean color, surface discoloration, and overall appearance; however, the day effect was significant. Mean scores for lean color, surface discoloration, and overall appearance consistently declined as number of days increased. A significant decline was observed between d 3 and d 4 for all analyses (data not reported), and mean off-odor score for all chops was 5.44 ("modest" off-odor).

Implications

The performance of the Spanish x Angora goats in this study indicates that crossbreeding Angoras with meat-type goats is feasible for producing goat carcasses comparable with the Boer x Spanish and Spanish goat carcasses. Future research should include Boer x Angora animals to determine if this crossbreed could be an additional option for goat producers. Breed-type did not have an effect on retail shelf-life; however, more work needs to be done to improve shelf-life of goat meat. Efforts also should be made to further examine other aspects of the meat goat industry, including carcass composition and palatability attributes.

Figure 1. Mean percent intermuscular fat, total side for feedlot meat- and fiber-type goats.



[abc]Means with different superscripts are different (P < .05)

Literature Cited

Jones, L.L., and A.J. Wyse. 1993. The economic impact of the curtailment of price support payments to the wool and mohair industry of Texas. Department of Agricultural Economics. Texas A&M University, College Station.

NASS. 1994. National Agricultural Statistical Service. USDA.

Washington, DC. January 1, 1994.
Oman, J.S., D.F. Waldron, D.B. Griffin, and J.S. Savell. 1996. The effect of breed-type and feeding regimen on goat carcass characteristics. Texas Agric. Exp. Sta. Prog. Rep. CPR-5257.
SAS. 1991. SAS User's Guide: Statistics (4th Ed.). SAS Inst., Inc., Cary, NC.
Van Niekerk, W.A. and N.H. Casey. 1988. The Boer goat II. Growth, nutrient requirements, carcass and meat quality. Small Rumin. Res. 1:355.
Waldron, D.F., T.D. Willingham, P.V. Thompson, and J.E. Huston. 1996. Growth rate and feed efficiency of Boer x Spanish compared to Spanish goats. Texas Agric. Exp. Sta. Prog. Rep. CPR-5257.
Wanstedt, K.G. 1982. Quality of vacuum packaged lamb retail cuts. Master's Thesis. Texas A&M University. College Station.

Carcass Composition of Market Lambs Slaughtered at Different USDA Yield Grade Endpoints

K.D. Fritz, M.D. Menzies, C.L. Skaggs, D.S. Hale, J.D. Williams, and J.W. Savell

ABSTRACT

Ninety market lambs of commercial finewool (n = 30), Suffolk (n = 30) and finewool first (F1) cross (n = 30) breed types traced to the same genetic background were assigned randomly to one of five treatment groups (n = 18) to ascertain the effects of breed and sex on carcass characteristics and composition. Lambs were slaughtered at staggered intervals according to assigned fat thickness range (treatment) designated by the USDA yield grade equation. USDA yield and quality grade factors were obtained at 48 h postmortem. The left side of each carcass was fabricated into closely trimmed retail cuts, whereas the right side was dissected into knife-separable components to determine physical composition. With the exception of bone weight, sex class had no effect on carcass components (P > .05). In general, within each breed group, as yield grade increased, percentage of retail product decreased, percentage of total subcutaneous (s.c.) and seam fat increased, percentage of lean and bone decreased, and percentage of internal fat remained constant.

Introduction

In our health-conscious society, consumers are demanding less fat in all of the products they buy. Today's marketing system for slaughter lambs encourages overfattening because increases in carcass weight and dressing percentage are rewarded by the current pricing system. Hence, unwanted fat is passed down the chain to the retailer and consumer. Individuals interviewed across industry segments listed overfinished lambs as the number one marketing/merchandising problem (Williams, 1991).

Lamb carcasses in the U.S. are assigned, on a voluntary basis, a numerical yield grade, which is used to rank and classify these carcasses on an estimation of their saleable yield or percentage of boneless, closely trimmed retail cuts. An antemortem evaluation of subcutaneous fat thickness at the 12th-13th rib interface was utilized as one of the selection factors in this study. Currently, this carcass measurement is the only factor used to determine the USDA (1992) yield grade (YG).

Comprehension of fat partitioning and deposition in sheep is critical because fat accounts for most of the variation in lamb cutability. Therefore, the objective of this study was to determine the influence of sex class, breed type, and yield grade class on carcass composition and retail yield.

Experimental Procedure

Animals.

This study utilized commercial Rambouillet (finewool), Suffolk and Finewool first (F1) cross lambs to characterize the current market lamb supply in Texas. To minimize the variation present among animals, lambs of similar genotype in each of the three breeds were selected, with 15 wethers and 15 ewes from each breed. The Suffolk lambs were purchased from two producers who use the same genetic base to produce Suffolk market lambs. The Commercial finewool and F1 lambs were purchased from one producer who uses the identified Suffolk line in his crossbreeding program. Ninety feeder lambs (60 to 70 lb) were bought and transported to the Texas A&M Sheep Center. Upon arrival, three males and females from each breed type were assigned randomly to one of five yield grade (YG) treatment groups (n = 18), devised to simulate the fat thickness ranges designated by the USDA (1992) Yield Grade equation.

The lambs were evaluated periodically and visually appraised by a team of three experienced livestock evaluators, who individually evaluated each lamb and compared estimates of fatness before making a collective decision. Lambs were slaughtered at staggered intervals, when the evaluators determined that the lambs had reached their assigned fat thickness.

All lambs were slaughtered at the Texas A&M University Rosenthal Meat Science and Technology Center using normal industry practices. The carcasses were evaluated for USDA quality and yield grade characteristics by trained carcass evaluators at 48 h postmortem. Kidney and pelvic fat (KP) was not removed during slaughter and was left intact until fabrication.

Fabrication.

The right side of each carcass was dissected into knife-separable components of subcutaneous fat, seam fat, internal fat, lean, and bone to determine physical composition. The left side was fabricated into closely trimmed retail cuts to determine the saleable yield of each

carcass, and was fabricated similar to the cutting styles utilized by Lorenzen et al. (1995). Combined retail product from the leg, loin, rack, and shoulder as a percentage of cold side weight, with kidney and pelvic fat removed, was calculated.

Statistical analysis.

Data were analyzed by analysis of variance using the general linear model (GLM) procedure of SAS (1991). A completely randomized design in a 5 (yield grade class) X 3 (breed type) X 2 (sex class) factorial arrangement was utilized. Due to unequal cell sizes, least squares means, and associated standard errors, were generated. Mean separations were performed using Least Significance Difference with a pre-determined significance level of $P < .05$.

Results and Discussion

Table 1 reports the means and standard deviations of various carcass characteristics. Percentages of carcass components by yield grade class and breed type are located in Table 2. In general, within each breed group, as yield grade class increased, percentage s.c. fat increased, percentage lean trim and bone decreased, and internal fat remained constant. Table 3 presents the least squares means for retail percentages. YG 4 and 5 yielded the lowest percentages of trimmed retail product and the highest percentages of s.c. fat ($P < .05$). No difference ($P > .05$) in percentage of internal fat was observed across YG groups.

These results agree with the findings of Garrett et al. (1990), who reported that yield grade made a significant difference in dissectible components and carcass retail yield, and with Rouse et al. (1970), who found that as lambs increase in weight, the biggest observed difference in percentage deposition was fat.

Table 1. Mean carcass traits (n = 88)

Measurement	Mean	SD	Min	Max
12th rib fat thickness, in.	.30	.12	.10	.60
Carcass weight, lb	68.66	16.19	40.90	14.61
KP fat, %[a]	4.39	1.77	1.56	11.20
Leg score[b]	11.88	1.16	10.00	14.00
Ribeye area, $in.^2$	2.52	.41	1.65	3.85
Body wall thickness, in.	.91	.36	.18	1.80
USDA quality grade[c]	11.61	1.07	10.00	15.00

[a] KP = actual percentage of kidney and pelvic fat removed before fabrication.
[b] Leg conformation score (10 = Low Choice, 11 = Average Choice, 12 = High Choice, etc.).
[c] USDA quality grade (10=Low Choice, 11=Average Choice, 12=High Choice, etc.).

YG 4 and 5, lamb carcassses exceeding .36 in fat depth at the 12th-13th rib interface yielded the lowest percentage of retail product and the highest percentage of s.c. fat. In order to improve consumer acceptance of lamb, the industry must take action to produce a leaner product, and the overfattening of market lambs must be discouraged economically.

Literature Cited

Garrett, R.P., J.W. Savell, S.G. May, H.K. Johnson, and H.R. Cross. 1990. Role of yield grade and carcass weight on the composition of lamb carcasses. J. Anim. Sci. 68:1299.

Lorenzen, C.L., A.M. Martin, D.B. Griffin, J.P. Walter, J.W. Savell, H.K. Johnson, T.R. Dockerty and R. Harbaugh. 1995. Communicating Lamb Value to the Retailer. Special Report to the Lamb Committee, National Livestock and Meat Board, Chicago, IL.

Rouse, G.H., D.G. Topel, R.L. Vetter, R.E. Rust, and, T.W. Wickersham. 1970. Carcass Composition of lambs at Different Stages of Development. J. Anim. Sci. 31: 846.

SAS. 1991. SAS User's Guide: Statistics (4th Ed.). SAS Institute, Inc., Cary, NC.

USDA. 1992. Official United States standards for grades of lamb, yearling mutton, and mutton carcasses. Agric. Marketing Serv., USDA, Washington, DC.

Williams, G.W. (Ed.). 1991. Assessment of Marketing Strategies to Enhance Returns to Lamb Producers. In: Texas Agricultural Market Research Center Report. TARMC Lamb Study Team, TARMC Commodity Market Research Report No. CM-1-91.

Table 2. Percentage carcass components

Breed	Component(%)	YG 1	YG 2	YG 3	YG 4	YG 5
Finewool	s.c. fat	14.60[b]	16.63[b]	17.98[b]	21.23[a]	20.73[a]
	seam fat	8.19[b]	9.63[b]	10.76[b]	13.13[a]	14.95[a]
	internal fat	2.51[a]	2.37[a]	3.15[a]	3.12[a]	2.15[a]
	lean	50.39[a]	49.32[a]	47.65[a]	44.05[b]	43.83[b]
	bone	23.29[a]	21.14[a]	19.67[b]	17.62[c]	17.68[c]
F1	s.c. fat	14.16[c]	17.08[bc]	18.60[ab]	22.07[a]	23.28[a]
	seam fat	11.12[b]	11.43[b]	11.27[b]	13.94[a]	14.29[a]
	internal fat	2.73[a]	2.66[a]	1.74[a]	1.76[a]	2.12[a]
	lean	50.48[a]	48.17[a]	49.02[a]	43.63[b]	42.71[b]
	bone	20.73[a]	19.75[ab]	18.51[bc]	17.54[c]	16.87[c]
Suffolk	s.c. fat	12.02[c]	15.46[bc]	18.44[b]	19.21[a]	21.32[a]
	seam fat	7.52[b]	11.57[a]	12.86[a]	13.25[a]	12.62[a]
	internal fat	1.71[a]	1.94[a]	2.01[a]	1.68[a]	2.25[a]
	lean	55.15[a]	50.24[b]	46.99[c]	47.34[bc]	43.63[c]
	bone	22.78[a]	19.90[b]	18.68[bc]	17.82[c]	19.27[bc]

[a, b, c] Least squares means within a row lacking a common superscript differ (P < .05).

Table 3. Percentage retail components

Breed	Component (%)	YG 1	YG 2	YG 3	YG 4	YG 5
Finewool	retail[e]	46.14[a]	46.45[a]	43.28[b]	42.34[c]	40.21[c]
	lean	9.64[a]	7.56[b]	7.01[b]	6.17[c]	6.52[bc]
	bone	14.44[a]	13.77[a]	13.17[a]	11.24[b]	10.12[b]
	s.c. fat	10.45[c]	11.52[bc]	13.34[b]	17.09[a]	19.17[a]
	seam fat	.74[b]	2.19[ab]	2.74[a]	3.43[a]	3.05[a]
	internal fat	1.18[b]	1.89[ab]	2.51[a]	2.58[a]	2.39[a]
F1	retail[e]	45.95[a]	45.01[a]	45.06[a]	40.37[b]	39.72[b]
	lean	8.08[a]	6.58[b]	6.82[ab]	6.14[b]	6.42[b]
	bone	15.40[a]	13.55[b]	12.61[b]	11.62[bc]	10.32[c]
	s.c. fat	10.10[d]	12.34[c]	12.66[c]	17.18[b]	20.35[a]
	seam fat	1.99[b]	2.69[b]	3.15[ab]	4.17[a]	3.58[a]
	internal fat	1.62[a]	2.32[a]	2.47[a]	2.26[a]	2.40[a]
Suffolk	retail[e]	48.81[a]	47.03[ab]	44.88[b]	41.91[c]	41.90[c]
	lean	9.61[a]	7.27[b]	6.25[b]	6.29[b]	5.99[b]
	bone	13.59[a]	13.07[a]	11.67[b]	11.06[b]	12.18[b]
	s.c. fat	7.41[d]	10.63[c]	13.79[b]	14.83[ab]	16.79[a]
	seam fat	.65[b]	2.41[a]	3.15[a]	3.32[a]	3.26[a]
	internal fat	1.48[b]	1.86[b]	2.26[ab]	2.46[a]	2.73[a]

[a, b, c, d] Means within a row lacking a common superscript differ (P < .05).

[e] Retail = retail product from the leg, loin, rack, and shoulder as a percentage of cold side weight with kidney and pelvic fat removed.

Growth, Composition, and Palatability Traits of Market Lambs Expressing Extreme Muscle Hypertrophy

K.J. Goodson, J.W. Savell, and R.K. Miller

ABSTRACT

Dorset x Suffolk crossbred wethers expressing a normal phenotype (control, n = 10) and extreme muscle hypertrophy, or Callipyge, phenotype (CLPG, n = 9) were fed individually and slaughtered upon reaching maximum growth potential (approximately 120 lb). CLPG had higher feed conversion and were more efficient in lean deposition ($P < .05$). Carcass weights did not differ, but fat thickness was lower (.12 in. vs .22 in.), ribeye area was greater (3.7 $in.^2$ vs 2.5 $in.^2$), and USDA yield grade was improved (1.6 vs 2.6) for CLPG carcasses ($P < .05$). CLPG carcasses demonstrated higher cutability and a more desirable muscle to bone ratio, with less fat and more lean as a percentage of total side weight ($P < .05$). Muscle from control lambs had lower calpastatin activity per gram of muscle (3.1 vs 2.5), higher fat percentages and lower moisture percentages ($P < .05$). Sarcomeres from CLPG biceps femoris were the longest ($P < .05$) whereas other muscles were similar. Total amount of collagen did not differ between treatment; however, percent solubility was highest in the longissimus muscle ($P < .05$). Shear force values did not differ between control and CLPG biceps femoris while CLPG longissimus muscle had higher ($P < .05$) shear force values than control longissimus muscle (7.98 vs 4.32 lb). Biceps femoris did not differ between control and CLPG in trained sensory panel myofibrillar or overall tenderness or connective tissue amount ratings. However, CLPG longissimus muscle received the lowest tenderness ratings (5.0, 6.1, and 4.9, respectively) and the control longissimus muscle received the highest ($P < .05$; 7.0, 7.1, and 6.9, respectively). These data suggest that while lambs expressing extreme muscle hypertrophy are superior in efficiency of growth and composition, quality and palatability of some muscles may be affected negatively.

Introduction

Consumer demands are forcing all segments of the meat industry to decrease fat and increase leanness in products. "The National Survey of Lamb Carcass Cutability Traits" (Tatum et al., 1989) reported that a large proportion of lamb carcasses were excessively fat. In that survey, the average fat thickness at the 12th/13th rib was 0.29 in. and over 39% of the samples were USDA yield grade four and five. This survey illustrated that the U.S. lamb industry has been moving backwards because the average fat thickness for lamb was 0.18 in. in 1969 (Southam and Field, 1969). Individuals interviewed across industry segments cited overfinished lambs as the major marketing/merchandising problem (Williams, 1991). The second most important problem in marketing lamb was the high retail prices. These high prices are attributed to the relatively small serving sizes. To improve consumer acceptance of lamb products, the lamb industry must take action to produce a leaner product.

Recently, a genetic mutation that causes extreme muscling in sheep was identified (Cockett et al., 1994). Market lambs that display this extreme muscle hypertrophy phenotype, referred to as Callipyge, are very lean and muscular in appearance. Whereas this phenotype seems desirable to the producer, there remain questions about the use of these extremely muscular animals in the meat industry. With the possible benefits from the inclusion of this phenotype into the commercial lamb population from a producer standpoint, the objective of this study was to determine the effect of extreme muscle hypertrophy on animal growth, carcass composition, and meat palatability characteristics.

Experimental Procedure

Dorset x Suffolk crossbred wethers expressing a normal phenotype (control, n = 10) and extreme muscle hypertrophy (CLPG, n = 9) were obtained and fed at the Texas A&M University Sheep Center. Lambs were fed 2 lb twice daily in feeding crates with individual stalls so that feed consumption could be measured for each lamb. Live weights were collected on each lamb every 7 d throughout the feeding period. Lambs were slaughtered at the Rosenthal Meat Science and Technology Center upon reaching maximum growth potential (approximately 120 lb). To characterize the population, live weight (lb), hot carcass weight (lb), fat thickness (in.), ribeye area ($in.^2$), and kidney and pelvic fat (%) were measured, and a USDA yield grade was assigned to each animal. Carcasses were split for fabrication of both sides and dissection of the left side. Each side was fabricated into a rough leg, loin, rack, and shoulder, neck, breast, plate, flank, and shank. Weights were recorded for each cut from the left side and then cuts were separated by physical dissection into lean tissue, fat, and bone and heavy connective tissue. From each carcass, biceps femoris (BF), semitendinosus (ST), semimembranosus (SM), longissimus muscle (LD), and triceps brachii (TB)

were identified and samples excised for subsequent analysis. Calpastatin enzyme activity at 24 h postmortem (Shackelford et al., 1994), sarcomere length (Cross et al., 1981), percent collagen and solubility (Cross et al., 1973), and fat and moisture percentages (AOAC, 1990) were determined for the five muscles. Warner-Bratzler shear force and trained sensory panel evaluations (Cross et al., 1978) of BF and LD were determined. Data were analyzed using GLM procedure of SAS (1990) with a significance level of $P < .05$. Unadjusted means were reported for live animal and carcass characteristics, and means were separated using Tukey's Studentized Range Test ($P < .05$). Least squares means were generated for chemical, sensory, and shear attributes. These means were tested for significance ($P < .05$) using Bonferroni's procedure (Lenter and Bishop, 1993).

Results and Discussion

Control lambs had a lower feed conversion ratio ($P < .05$) combined with higher feed consumption, indicating they were less efficient from a production standpoint. CLPG lambs were more efficient at depositing lean with minimal fat while requiring less feed energy (Table 1).

Table 1. Mean growth data ± SE of control and Callipyge lambs

Trait[a]	Control	Callipyge
Average daily gain	.24 ± .01	.22 ± .01
Feed conversion	4.28^{b} ± .02	3.90^{c} ± .03
Daily feed intake	3.51 ± .03	3.40 ± .03
Live weight, kg	125.0^{b} ± .6	115.3^{c} ± .9

[a]Traits: Average daily gain (lb d), Feed conversion (lb of feed per lb of gain) and daily feed intake (lb each d).
[b, c] Means within a row lacking a common superscript differ ($P < .05$).

Carcass weights did not differ, but fat thickness was lower, ribeye area was higher, and USDA yield grade was lower for lambs expressing extreme muscle hypertrophy (Table 2). There was no ($P > .05$) treatment by muscle interaction for calpastatin activity; however, there was a significant treatment effect. CLPG muscles had higher ($P < .05$) calpastatin activity levels than control muscles (3.11 vs 2.47). Across muscles, those from the leg had similar ($P > .05$) calpastatin activity levels (BF = 2.64, ST = 2.89, SM = 2.64), but the TB had the highest ($P < .05$) activity level (3.35). The LD muscle had the lowest calpastatin activity (2.43) but did not differ in activity from the BF and SM. CLPG muscles exhibited a higher ($P < .05$) percentage of moisture than the control group (74.71 vs 73.74). There was no ($P < .05$) treatment by muscle interaction for total collagen amount; however, there were differences in solubility as affected by muscle. LD had the highest percent solubility while the BF, SM, and TB had the lowest.

Table 2. Mean carcass characteristics and dissectable components (percent of side weight) ± SE of control (n = 10) and Callipyge (n = 9) lambs

Trait	Control	Callipyge
Hot carcass weight, lb	71.2 ± .7	71.0 ± .7
Fat thickness, in.	$.22^{a}$ ± .05	$.12^{b}$ ± .05
Ribeye area, $in.^2$	2.5^{b} ± .9	3.7^{a} ± .6
Kidney/pelvic fat, %	1.7 ± .2	1.1 ± .2
USDA yield grade	2.6^{a} ± .2	1.6^{b} ± .2
Fat, %	29.0^{b} ± 1.7	19.7^{a} ± 1.9
Lean, %	48.5^{b} ± 1.5	60.0^{a} ± 1.6
Bone, %	16.6 ± .6	15.2 ± .5

[a,b] Means within a row lacking a common superscript differ ($P < .05$).

Fat percentages (Table 3), except for the BF, were higher for the control muscles vs the CLPG muscles. Sarcomeres from the CLPG BF were the longest while other muscles were similar. Between muscles, BF and ST had longer sarcomere lengths than SM, LD, and TB. Shear force values did not differ between control and CLPG BF. Shear force values for control LD were lowest, but did not differ from BF. CLPG LD had the highest shear values, but did not differ from either the control or CLPG BF.

Table 3. Least squares means for treatment x muscle effect on sarcomere length (μm), fat (%), and Warner-Bratzler shear force (lb)

Muscle	Control	Callipyge
Sarcomere length (μm)		
Biceps femoris	1.85^{b}	1.96^{a}
Semitendinosus	1.87^{b}	1.82^{bc}
Semimembranosus	1.75^{d}	1.74^{d}
Longissimus muscle	1.77^{cd}	1.72^{d}
Triceps brachii	1.73^{d}	1.70^{d}
Fat (%)		
Biceps femoris	$.22^{e}$	$.12^{e}$
Semitendinosus	6.36^{a}	2.71^{cd}
Semimembranosus	3.46^{bc}	1.88^{d}
Longissimus muscle	4.07^{b}	1.92^{d}
Triceps brachii	3.60^{bc}	2.37^{d}
Shear force (lb)		
Biceps femoris	6.42^{ab}	6.92^{ab}
Longissimus muscle	4.32^{b}	7.98^{a}

[a,b,c,d,e] Means within a subheading lacking a common superscript differ ($P < .05$).

There was a treatment by muscle interaction ($P < .05$) for sensory panel tenderness and connective tissue amount ratings (Table 4). The BF did not differ between control and CLPG in myofibrillar or overall tenderness or for connective tissue amount. However, CLPG LD received the lowest tenderness ratings, and the control LD received the highest. This interaction followed that observed for shear force values.

Feed efficiency and carcass traits favored lambs expressing extreme muscle hypertrophy. CLPG lambs required less feed energy to produce leaner, trimmer carcasses. However, muscle from control lambs had lower calpastatin levels, lower shear force values, and higher sensory scores. Presence or absence of the CLPG

Table 4. Least squares means for treatment by muscle effect on sensory attributes

Sensory attribute[a] / muscle	Control	Callipyge
Myofibrillar tenderness		
Biceps femoris	6.2[c]	5.9[c]
Longissimus muscle	7.0[b]	5.0[d]
Connective tissue		
Biceps femoris	6.0[c]	6.3[c]
Longissimus muscle	7.1[b]	6.1[c]
Overall tenderness		
Biceps femoris	6.0[c]	6.0[c]
Longissimus muscle	6.9[b]	4.9[d]

[a] Sensory attributes were rated on an eight point scale where 1 = extremely tough, abundant connective tissue; 8 = extremely tender, no connective tissue.
[b,c,d] Means within a sensory attribute lacking a common superscript differ ($P < .05$).

gene had a significant effect on LD, whereas BF was not affected. Therefore, while lambs expressing extreme muscle hypertrophy are superior in growth and composition, quality and tenderness of some muscles may be affected negatively.

Literature Cited

AOAC. 1990. Official Methods of Analysis (15th Ed.). Assoc. of Official Analytical Chemists, Arlington, VA.

Cockett, N.E., S.P. Jackson, T.L. Shay, D. Nielson, S.S. Moore, M.R. Steele, W. Barendese, R.D. Green, and M. Georges. 1994. Chromosomal localization of the *Callipyge* gene in sheep (*Ovis aries*) using bovine DNA markers. Proc. Natl. Acad. Sci. 91:3019.

Cross, H.R., Z.L. Carpenter, and G.C. Smith. 1973. Effects of intramuscular collagen and elastin on bovine muscle tenderness. J. Food Sci. 38:998.

Cross, H.R., R. Moen, and M.S. Stanfield. 1978. Training and testing of judges for sensory analysis of meat quality. Food Tech. 32:48.

Cross, H.R., R.L. West, and T.R. Dutson. 1981. Comparison of methods for measuring sarcomere length in beef \semi-tendinosus muscle. Meat Sci. 5:261.

Lenter, M., and T. Bishop. 1993. Experimental Design and Analysis (2nd Ed.). Valley Book Company. Blacksburg, VA.

SAS. 1990. SAS User's Guide: Statistics. SAS Inst., Cary, NC.

Shackelford, S.D., M. Koohmaraie, L.V. Cundiff, K.E. Gregory, G. A. Rohrer, and J.W. Savell. 1994. Heritabilities and phenotypic and genetic correlations for bovine postrigor calpastatin activity, intramuscular fat content, Warner-Bratzler shear force, retail product yield, and growth rate. J. Anim. Sci. 72:857.

Southam, E.R., and R.A. Field. 1969. Influence of carcass weight upon carcass composition and consumer preference for lamb. J. Anim. Sci. 28:584.

Tatum, J.D., J.W. Savell, H.R. Cross, and J.G. Butler. 1989. A national survey of lamb cutability traits. SID Res. J. 5(1):23.

Williams, G.W. (Ed.). 1991. Assessment of Marketing Strategies to Enhance Returns to Lamb Producers. In: Texas Agricultural Market Research Center Report. TARMC Lamb Study Team, TARMC Commodity Market Research Report No. CM-1-91.

Evaluation of Live Animal and Carcass Measurements to Predict Lamb Carcass Composition and Retail Yield

K.D. Fritz, M.D. Menzies, C.L. Skaggs, D.S. Hale, J.D. Williams, and J.W. Savell

ABSTRACT

Lambs of similar genotype (n = 90) from three breed types (commercial finewool, Suffolk, and finewool first (F1) cross) were selected for use in this study. Three ewes and three wethers from each breed type were assigned randomly to one of five yield grade treatment groups (n = 18), devised to simulate the fat thickness ranges designated by the USDA yield grade equation. The lambs were evaluated periodically by a team of three experienced livestock evaluators and a live estimation of fat thickness, along with several other linear measurements were recorded for each lamb. Lambs were slaughtered at staggered intervals when the evaluators had determined that the lamb had reached its assigned fat thickness. USDA yield and quality grade factors were obtained at 48 h postmortem. The left side of each carcass was fabricated into closely trimmed retail cuts, while the right side was dissected into knife-separable components to determine physical composition. As yield grade class increased, days on feed and live weight increased proportionately. A live estimation of fat thickness was correlated to percentage retail yield and the separable components of subcutaneous (s.c.) fat and seam fat. Weight of kidney and pelvic fat (lb removed during fabrication) was correlated to percentage separable seam fat.

Introduction

Demand for lamb has declined some 33% in the past 20 yr. The projected U.S. 1995 per-capita consumption of lamb is 1.1 lb. This, coupled with the loss of wool incentive payments, puts the viability and absolute survival of the sheep industry in the U.S. at a tremendous risk. The present market system does not recognize true carcass merit or value, but instead rewards additional weight and dressing percentage.

In order for the lamb industry to maintain and improve current market share, the ability to identify, produce, and properly manage lean, high cutability lambs must be its foremost concern.

Lamb carcasses in the U.S. are assigned, on a voluntary basis, a numerical yield grade, which is used to rank and classify these carcasses on an estimation of their saleable yield or percentage of closely trimmed retail cuts. The current equation and measurements utilized were changed and adopted for usage by the United States Department of Agriculture (USDA, 1992). The current equation utilizes only one measurement, subcutaneous fat thickness at the 12th rib, removing kidney and pelvic fat (KP) and leg conformation score from consideration. The accuracy values associated with the current yield grading system are significantly lower than the values of the previous equation (Smith et al., 1969).

Many packers and retailers believe that the amount of KP and the amount of seam fat in a lamb carcass are closely correlated, and that removal of KP eliminates the possibility for using that trait to predict the amount of seam fat in lamb carcasses. The "National Lamb Market Basket Survey" (Harris *et al.*, 1990) reported that 44.8% of the separable fat in the surveyed retail cuts was external fat, whereas 52.2% was seam fat. This report also concluded that "lamb retail cuts, as they are presented to the consumer today, do not have excessive amounts of external fat; however, there is excessive seam fat in many retail cuts."

According to Edwards *et al.* (1989), the best predictor of market lamb composition is still a subjective estimate of fatness by an experienced livestock evaluator. Other researchers have reported that linear measurements could have value in a live animal selection program (Cassard *et al.*, 1969; Orme *et al.*, 1962).

Therefore, the objective of this study was to determine the relationship between live animal and carcass measurements and characteristics and lamb carcass composition and retail yield.

Experimental Procedure

Animals.

This study utilized commercial Rambouillet (finewool), Suffolk and finewool first (F1) cross lambs to characterize the current market lamb supply in Texas. To minimize the variation present among animals, lambs of similar genotype in each of the three breeds were selected, with 15 wethers and 15 ewes from each breed. The Suffolk lambs were purchased from two producers who use the same genetic base to produce Suffolk market lambs. The commercial finewool and F1 lambs were purchased from one producer who uses the identified Suffolk line in his crossbreeding program. Ninety feeder lambs (60 to 70 lbs.) were bought and transported to the Texas A&M Sheep Center.

Upon arrival, three males and females from each breed type were assigned randomly to one of five yield grade (YG) treatment groups (n = 18), devised to

simulate the fat thickness ranges designated by the USDA (1992) Yield Grade equation. After a backgrounding program (starter diet) for 2 wk, the lambs were weighed and evaluated for frame size and fat thickness. Lambs were allowed to consume their diets on an *ad libitum* basis and received a constant supply of fresh water.

The lambs were evaluated periodically and visually appraised by a team of three experienced livestock evaluators, who individually evaluated each lamb and compared estimates of fatness before making a collective decision. Lambs were slaughtered at staggered intervals when the evaluators determined that the lambs had reached their assigned fat thickness. Before slaughter, the lambs were measured for shoulder height, heart girth, body length, and forearm circumference, and live weights were recorded.

All lambs were slaughtered at the Texas A&M University Rosenthal Meat Science and Technology Center using normal industry practices. All carcasses were evaluated for USDA quality and yield grade characteristics by trained carcass evaluators at 48 h postmortem. Additional carcass measurements and characteristics were recorded. Kidney and pelvic fat (KP) was not removed during slaughter and was left intact until fabrication.

Fabrication.

The right side of each carcass was dissected into knife-separable components of subcutaneous fat, seam fat, internal fat, lean, and bone to determine physical composition. The left side was fabricated into closely trimmed retail cuts to determine the saleable yield of each carcass and was fabricated similar to the cutting styles utilized by Lorenzen et al. (1995). The following weights and percentages were recorded for the left side: untrimmed primal weight = combined weight of rough leg, loin, rack, and shoulder; total retail product = combined weight of closely trimmed retail product from the leg, loin, rack, and shoulder; primal retail yield = total retail product/untrimmed primal weight; percentage side retail yield = total retail product/cold side weight; and percentage side retail yield (KP out) = total retail yield/cold side weight with KP removed.

Statistical analysis.

Data were analyzed by analysis of variance using the general linear model (GLM) procedure of SAS (1991). A completely randomized design in a 5 (yield grade class) X 3 (breed type) X 2 (sex class) factorial arrangement was utilized. Due to unequal cell sizes, least squares means, and associated standard errors, were generated. Mean separations were performed using Least Significance Difference with a pre-determined significance level of $P < .05$. Pearson's correlation coefficients were used to determine the relationship between the dependent (compositional) variables and the independent (live animal and carcass measurements) variables.

Results and Discussion

Live and Carcass Measurements.

Tables 1 and 2 report the live animal and carcass measurements for each yield grade class. As days on feed increased, yield grade class, live weight, and carcass weight also increased ($P < .05$).

Yield grades 4 and 5 had the most fat in the shoulder pocket, and over the breast, sirloin, and dock and the most KP ($P < .05$), as well as the greatest leg, shoulder, and loin circumferences.

Correlation Coefficients.

Simple correlation coefficients between live measurements and yield grade class and retail weights and percentages are reported in Table 3. A live estimation of subcutaneous fat thickness was correlated ($P < .001$) to actual yield grade class (.82) and negatively correlated ($P < .001$) to percentage side retail yield with KP in (-.75) and KP out (-.72). Days on feed was correlated ($P < .001$) to yield grade class (.67). Live weight was correlated ($P < .001$) to actual yield grade class (.71) and weight of total retail product (.90).

Table 4 reports the simple correlation coefficients between carcass measurements and yield grade class and retail weights and percentages. Fat thickness at the 12th-13th rib was negatively correlated ($P < .001$) to both percentage of primal retail yield (-.63) and to side retail yield (-.75). Fat thickness over the neck was negatively correlated ($P < .001$) to percentage of primal retail yield (-.61) and to side retail yield (-.73). Yield grade class was negatively correlated to percentage side retail yield (-.73). Although carcass weight was correlated ($P < .001$) to weight of retail product (.97) and to yield grade class (.71), it shared a negative correlation ($P < .001$) with percentage primal retail yield (-.34).

Table 5 reports the correlation coefficients between live measurements and side dissectable components. Estimated fat was negatively correlated ($P < .001$) to percentage lean (-.59), and percentage bone (-.67), and correlated ($P < .001$) to percentage s.c. fat (.58) and percentage seam fat (.65). Days on feed was correlated ($P < 001$) to percentage s.c. fat (.36) and percentage seam fat (.60). Live weight was negatively correlated ($P < .001$) to percentage lean (-.53) and percentage bone (-.55) and correlated ($P < .001$) to percentage seam (.69) and percentage s.c. fat (.48).

Table 6 presents the correlation coefficients between intact carcass measurements and side dissectable components. Probe fat at the 12th-13th rib was correlated ($P < .001$) to percentage s.c. fat (.68) and percentage

seam fat (.70). Carcass weight was negatively correlated ($P < .001$) to percentage bone (-.59) and correlated ($P < .001$) to percentage percentage s.c. fat (.43) and percentage seam (.71). Leg, loin, and sirloin circumferences were negatively correlated ($P < .001$) to percentage lean and correlated ($P < .001$) to percentage seam and s.c. fat.

Lambs fed to fatter live endpoints required more days on feed and additional pounds in live weight. A live estimation of s.c. fat thickness at the 12th rib was significantly related to percentage of carcass components and percentage retail yield. Intact carcass measurements offered similar correlation coefficients with these components.

Implications

Today the consumer dictates demand for red meat products, and the consumer wants a lean, uniform, convenient product. Overfat lamb carcasses and uniformity are still major problems haunting the lamb industry. The production of leaner slaughter lambs may provide an opportunity to improve lamb merchandising. This must be accomplished for the lamb industry to keep stride with competitive meat products.

In spite of the many challenges facing the U.S. lamb industry, consumer preferences and true product value have not been clearly communicated through the marketing chain back to the producer. Selection for leanness in market lambs must be emphasized and justly rewarded.

Literature Cited

Cassard, D.W., C. M. Bailey and L. G. McNeal. 1969. Evaluation of factors affecting lamb carcass charcateristics. J. Anim. Sci. 28:305.

Edwards, J. W., R. C. Cannell, R. P. Garrett, J. W. Savell, H. R. Cross and M. T. Longnecker. 1989. Using ultrasound, linear measurements and live fat thickness estimates to determine the carcass composition of market lambs. J. Anim. Sci. 67:3322.

Harris, J.J., J.W. Savell, R.K. Miller, D.S. Hale, D.B. Griffin, L.C. Beasley, and H.R. Cross. 1990. A National Market Basket Survey for Lamb. J. Food Qual. 13:453.

Lorenzen, C. L., A. M. Martin, D. B. Griffin, J. P. Walter, J. W. Savell, H. K. Johnson, T. R. Dockerty and R. Harbaugh. 1995. Communicating Lamb Value to the Retailer. Special Report to the Lamb Committee, National Live Stock and Meat Board, Chicago, IL.

Orme, L. E., R. E. Christian and T. D. Bell. 1962. Live animal and carcass indices for estimating the carcass composition in lambs. J. Anim. Sci. 21:666.

SAS. 1991. SAS User's Guide: Statistics (4th Ed.). SAS Institute, Inc., Cary, NC.

Smith, G.C., Z.L. Carpenter, and G.T. King. 1969. Ovine carcass cutability. J. Anim. Sci. 36:432.

USDA. 1969. Official United States standards for grades of lamb, yearling mutton, and mutton carcasses. Agric. Marketing Serv., USDA, Washington, DC.

USDA. 1992. Official United States standards for grades of lamb, yearling mutton and mutton carcasses. Agric. Marketing Serv., USDA, Washington, DC.

Table 1. Least Squares Means (SE) for live animal measurements for each yield grade

Measurement	YG 1 (n = 11)	YG 2 (n = 30)	YG 3 (n = 16)	YG 4 (n = 22)	YG 5 (n = 9)
Frame score[d]	2.08	2.01	1.94	2.08	2.16
	(.14)	(.08)	(.11)	(.08)	(.14)
Days on feed	60.16[c]	75.58[c]	105.14[b]	168.82[a]	186.67[a]
	(17.01)	(9.48)	(13.82)	(10.76)	(17.68)
Average daily gain,	.29[b]	.32[b]	.35[ab]	.41[a]	.38[ab]
lb/day	(.05)	(.03)	(.04)	(.03)	(.05)
Estimated fat, in.	.11[d]	.20[c]	.31[b]	.41[a]	.44[a]
	(.03)	(.02)	(.02)	(.02)	(.03)
Heart girth, in.	32.32	31.69	33.65	34.22	35.46
	(1.57)	(.88)	(1.28)	(1.07)	(1.81)
Height, in.	26.43[b]	28.99[ab]	29.07[a]	31.57[a]	31.79[a]
	(1.46)	(.82)	(1.19)	(.99)	(1.68)
Length, in.	25.88	26.21	26.79	28.33	28.88
	(.53)	(.30)	(.44)	(.36)	(.62)
Forearm circumference, in.	8.58[b]	8.62[b]	8.85[ab]	9.32[a]	9.29[a]
	(.26)	(.15)	(.21)	(.18)	(.29)
Live wt, lb	100.06[d]	110.90[c]	124.74[b]	143.48[a]	151.76[a]
	(1.99)	(1.28)	(1.77)	(1.45)	(2.28)

[a,b, c] LSMeans within rows with different superscripts differ ($P < .05$).
[d] Frame score (1 = Small Framed, 2 = Average Framed, 3 = Large Framed).

Table 2. LSMeans (SE) for intact carcass measurements for each yield grade

Measurement	YG 1 (n = 11)	YG 2 (n = 30)	YG 3 (n = 16)	YG 4 (n = 22)	YG 5 (n = 9)
Carcass wt, lb	52.70[c]	59.24[c]	68.79[b]	81.55[a]	87.85[a]
	(3.24)	(1.81)	(2.63)	(2.05)	(3.37)
Probe fat, in.[f]	.14[e]	.23[d]	.30[c]	.38[b]	.51[a]
	(.02)	(.01)	(.01)	(.01)	(.02)
Shoulder pocket, in.	.37[c]	.51[b]	.59[b]	.81[a]	.83[a]
	(.06)	(.03)	(.05)	(.04)	(.06)
Breast, in.	.88[b]	.91[b]	.99[b]	1.11[a]	1.22[a]
	(.06)	(.04)	(.05)	(.04)	(.06)
Neck, in.	1.60[b]	1.72[b]	2.07[a]	2.36[a]	2.37[a]
	(.15)	(.08)	(.12)	(.09)	(.15)
Sirloin, in.	.27[c]	.33[c]	.41[b]	.50[a]	.52[a]
	(.04)	(.02)	(.03)	(.02)	(.04)
Dock, in.	.32[b]	.42[b]	.46[b]	.62[a]	.65[a]
	(.05)	(.03)	(.04)	(.03)	(.06)
Leg conformation	12.24	11.86	12.18	11.68	11.68
score[g]	(.26)	(.16)	(.23)	(.18)	(.29)
Leg circum., in.	26.59[c]	27.58[c]	28.89[b]	29.94[a]	30.33[a]
	(.47)	(.26)	(.38)	(.30)	(.49)
Leg width, in.	10.51[b]	10.56[b]	11.10[a]	11.21[a]	11.36[a]
	(.24)	(.13)	(.19)	(.15)	(.24)
Shoulder	31.43[c]	32.52[c]	34.06[b]	35.67[a]	36.35[a]
circumference, in.	(.52)	(.29)	(.43)	(.33)	(.55)
Loin circumference, in.	30.42[c]	31.65[c]	33.25[b]	34.63[ab]	36.54[a]
	(.79)	(.44)	(.65)	(.50)	(.83)
USDA quality grade[h]	11.40	11.26	11.77	12.06	11.83
	(.31)	(.19)	(.27)	(.22)	(.36)
KP, kg[i]	1.58[d]	2.17[d]	3.10[c]	4.18[b]	5.28[a]
	(.16)	(.10)	(.13)	(.11)	(.18)

[a,b, c, d, e] LSMeans within rows with different superscripts differ ($P < .05$).
[f] Probe fat is measurement at the 12th-13th rib interface.
[g] Leg conformation score (10 = Low Choice, 11 = Average Choice, 12 = High Choice, etc.).
[h] USDA quality grade (10 = Low Choice, 11 = Average Choice, 12 = High Choice, etc.).
[i] KP = lbs of kidney and pelvic fat removed prior to fabrication.

Table 3 . Simple correlation coefficients between live measurements and yield grade class and side retail product weights and percentages

Measurement	Yield grade class	Untrimmed primal wt, lb	Total retail product, lb	Primal retail yield, %	% Side retail yield[a], %	% Side retail yield (KP out)[b], %
Estimated fat, in.	.82**	.71**	.58**	-	-	-
Frame score[c]	.06	.14	.16	-.12	-.13	-.11
Days on feed	.67**	.70**	.67**	-.33**	-	-
Heart girth, in.	.24*	.40**	.38**	-.05	-.17	-.16
Length, in.	.54**	.74**	.72**	-.20	-	-
Height, in.	.40**	.37**	.34**	-.23*	-.35**	-
Forearm cir, in.	.28**	.67**	.70**	-.01	-.24*	-.28*
Live wt., lb	.71**	.95**	.90**	-	-	-

[a] % side retail yield is equated from the total retail product weight from the four major primals as a percentage of cold side weight.
[b] % side retail yield (KP out) is equated from the retail product weight from the four major primals as a percentage of cold side weight with kidney and pelvic fat removed.
[c] Frame Score (1 = Small Framed, 2 = Average Framed, 3 = Large Framed).
* P < .05
** P < .01
*** P < .001

Table 4. Simple correlation coefficients between carcass measurements and yield grade class and retail product weights and percentages

Measurement	Yield grade class	Untrimmed primal wt, lb	Total retail product, lb	Primal retail yield, %	% Side retail yield[a], %	% Side retail yield (KP out)[b], %
Probe fat, in	.98**	.70**	.56**	-	-	-
Carcass wt, lb	.71**	.97**	.97**	-	-	-
Leg score	-.21*	.20**	.32**	.31**	.20	.14
Shoulder, in.	.64**	.62**	.60**	-.35**	-	-
Breast, in.	.50**	.57**	.51**	-.30**	-	-
Neck , in.	.74**	.51**	.39**	-	-	-
Sirloin, in.	.65**	.62**	.54**	-	-	-
Dock, in.	.56**	.51**	.46**	-	-	-
Leg cir, in.	.56**	.94**	.94**	-.19	-	-
Leg width, in.	.31**	.71**	.77**	.04	-.17	-.18
Shoulder cir, in.	.70**	.94**	.89**	-	-	-
Loin cir , in.	.60**	.84**	.81**	-.29**	-	-
KP, lb	.73**	.53**	.62**	-	-	-
KPP, %	.59**	.28**	.20**	-	-	.55**

[a] Carcass measurements. Probe fat is measurement at the 12th-13th rib interface. KP = kg of kidney and pelvic fat. KPP = % kidney and pelvic fat.
[b] % side retail yield is equated from the total retail product weight from the four major primals as a percentage of cold side weight.
[c] % side retail yield (KP out) is equated from the retail product weightfrom the four major primals as a percentage of cold side weight with kidney and pelvic fat removed.
* P < .05
** P < .01
*** P < .001

Table 5 . Simple correlation coefficients between live measurements and percentage side dissectable components of lean, bone and fat

Measurement	Lean, %	Bone, %	S.c. fat, %	Seam fat, %	Internal fat, %
Estimated fat, in.	-	-	.58**	.65**	-.08
Frame score[a]	-.12	.11	-.03	.17	-.04
Days on feed	-	-	.36**	.60**	-.14
Heart girth, in.	.10	-.28	-.08	.25*	-.07
Length, in.	.42**	-	.40**	.47**	-.14
Height, in.	-	.11	.47**	.24	-.03
Forearm cir, in.	-.28*	-.23*	.21	.37**	-.20
Live weight, lb	-	-	.48**	.69**	-.22*

[a] Frame score (1 = Small Framed, 2 = Average Framed, 3 = Large Framed).
* P < .05
** P< .01
*** P < .001

Table 6. Simple correlation coefficients between carcass measurements and percentage side dissectable components of lean, bone and fat

Measurement	Lean, %	Bone, %	S.c. fat, %	Seam fat, %	Internal fat, %
Probe fat, in	-	-	.68**	.59**	-
Carcass wt, lb	-	-	.43**	.71**	-.24
Leg score	.43**	.04	-	-.05	-.33
Shoulder, in.	-	-	.37**	.57**	-.13
Breast, in.	-	-.28**	.32**	.45**	-.13
Neck , in.	-	-	.33**	.39**	-
Sirloin, in.	-	-	.39**	.54**	-
Dock, in.	-.33**	-	.34**	.42**	-.02
Leg cir, in.	-	-	.34**	.62**	-.30
Leg width, in.	-.16	-.35**	.11	.46**	-.24
Shoulder circum., in.	-	-	.48**	.73**	-.18
Loin circum. , in.	-	-	.38**	.63**	-.12
KP, lb	-	-	.44**	.70**	-.01
KPP, %	-	-	.42**	.53**	.13

[a] Carcass measurements. Probe fat is measurement at the 12th-13th rib interface. KP = kg of kidney and pelvic fat. KPP = % kidney and pelvic fat.
[b] % side retail yield is equated from the total retail product weight from the four major primals as a percentage of cold side weight.
[c] % side retail yield (KP out) is equated from the retail product weight from the four major primals as a percentage of cold side weight with kidney and pelvic fat removed.
* P < .05
** P< .01
*** P < .001

Influence of Various Marketing Styles of Wholesale Lamb on Retail Merchandising Options

C.L. Lorenzen, A.M. Martin, D.B. Griffin, J.P. Walter, T.R. Dockerty, H.K. Johnson, and J.W. Savell

ABSTRACT

Lamb carcasses (n = 94) from four major packers, selected to vary in weight class and fat thickness, were utilized to determine retail yield and labor requirements of wholesale lamb fabricated to different retail endpoints. It can be concluded that retail yield decreases and total processing time increases for innovative versus traditional fabrication methods when a comparison is made within subprimal. When wholesale purchasing options were compared, total retail yield did not differ ($P > .05$). Boxed subprimals had a shorter ($P < .05$) total processing time than lambs fabricated as whole carcasses or three-piece boxes. Increasing time required to perform innovative processing procedures would dictate that retailers increase price per pound to compensate for loss of time and yield. Lamb Computer Assisted Retail Decision Support (CARDS) software can assist retailers in determining estimates of what those numerical values may actually be.

Introduction

Lamb is currently sold as traditional, bone-in retail cuts which are presented to the consumer with little external fat cover (Harris et al., 1990). However, wholesale lamb can be purchased as a traditional carcass, a 3-piece boxed carcass, or as innovative, vacuum packaged subprimals. Although yields of innovative and traditional subprimals have been investigated (Garrett et al., 1990, 1992), little information exists for innovative and traditional retail fabrication comparisons. With the trend for meat sources to move to boneless retail cuts that are more consumer friendly, this study was conducted to investigate the salable yield of retail cuts from different wholesale lamb purchasing methods, and to use that information to develop a Lamb CARDS (Computer Assisted Retail Decision Support) software package.

Materials and Methods

Lamb carcasses (n = 94) from four major packers, selected to vary in weight class and fat thickness, were utilized to determine retail yield and labor requirements of wholesale lamb. Carcasses were shipped to Texas A&M University to be fabricated in a simulated retail cutting room by experienced meat cutters from Texas State Technical College. Lambs were allotted randomly according to weight class to be fabricated as whole carcasses (n = 20), three-piece boxes (n = 22), or subprimals (n = 52). Processing times (s) were recorded and wholesale and retail weights (kg) were obtained to calculate retail yield. Lambs, regardless of merchandising option, were fabricated into traditional, bone-in retail cuts, or innovative, boneless or semi-boneless retail cuts.

Results and Discussion

Overall, retail yield decreased and processing times increased as lamb subprimals were fabricated to a boneless or semi-boneless, innovative endpoint when compared to bone-in traditional retail cuts (data not shown in tabular form). Retail yield did not differ ($P > .05$) among wholesale purchasing methods (Table 1). Lambs purchased as subprimals had shorter ($P < .05$) total processing times than lambs fabricated as whole carcasses or three-piece boxes (Table 2).

Table 1. Comparison of total retail yield (%) by purchasing method

Purchasing method	Retail yield, %
Carcass	72.7
Three-piece box	72.9
Subprimal	68.5

Table 2. Comparison of total processing times (min) by purchasing method

Purchasing method	Processing time, m
Carcass	38.85
Three-piece box	37.66
Subprimal	23.35

Increasing time required to perform innovative processing procedures would dictate that retailers need to determine the amount they must increase price per pound to compensate for the loss of time and yield. This must also be evaluated with consumer expectations for meat products in terms of leanness and ease of preparation. In addition, the lack of difference in retail yield by merchandising option would indicate that retailers should

make purchasing decisions based on the product mix in the retail case. Data from this project has been used as the base for the Lamb Computer Assisted Decision Support (CARDS) software which aids retailers in making purchasing and marketing decisions. Lambs CARDS allows retailers to make comparisons of purchasing and marketing opportunities on a computer instead of by trial and error. It also encourages retailers to collect and use their own data to make dependable buying and marketing decisions.

Literature Cited

Garrett, R.P., J.W. Savell, S.G. May, H.K. Johnson, and H.R. Cross. 1990. Role of yield grade and carcass weight on the composition of lamb carcasses. J. Anim. Sci. 68:1299.

Garrett, R.P., J.W. Savell, H.R. Cross, and H.K. Johnson. 1992. Yield grade and carcass weight effects of the cutability of lamb carcasses fabricated into innovative style subprimals. J. Anim. Sci. 70:1829.

Harris, J. J., J. W. Savell, R. K. Miller, D. S. Hale, D. B. Griffin, L. C. Beasley, and H. R. Cross. 1990. A national market basket survey for lamb. J. Food Qual. 13:453.

Texas Agricultural Experiment Station

The Texas A&M University System

Copies printed: 1,000