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RESEARCH REPORTS

Sheep and Angora Goat, Wool and Mohair—1970

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RESEARCH REPORTS

Sheep and Angora Goat, Wool and Mohair—1970

Effect of Cooling Ewes at Mating on Reproductive Performance

MAURICE SHELTON

Prior research has shown a manifold adverse effect of high temperature stress on reproductive performance of many species, and sheep are among those most susceptible. The first reported and continued most serious effect of high temperature stress on fertility is the effect on spermatogenesis of rams. The extent of this problem in the McGregor area was studied by Shelton (1952). Subsequently, Yeates (1958), Shelton (1964), and Goode (1964) showed that high temperature stress during the latter part of pregnancy can cause fetal dwarfing and increased death losses. Reduced birth weight remains a characteristic of fall-born lambs, but the above workers have suggested control measures adequate to prevent extreme death losses. More recently, workers at North Carolina (Ulberg, 1958 and Alliston and Ulberg, 1961) and Kentucky (Dutt, 1963 and 1964) showed that high temperature stress for a 9-day period from 1 day previous to 8 days after mating can cause embryo loss. Since high environmental temperatures are generally prevalent in the McGregor area at times of mating for fall or winter lambs, the effect of heat stress at mating time and reproductive performance of ewes mated in the summer were studied. Three field trials were conducted at the McGregor Center to investigate a possible beneficial effect of cooling at mating. The first of these was conducted before the critical period had been properly identified, and the animals were cooled for only 1 day. No benefits were obtained from cooling, and details of this trial are not reported.

Experimental Procedure

1967 Trial

On July 1, 1967, approximately 100 head of mature Rambouillet ewes were divided into two groups:

Control—these were run with two rams on pasture.

Cooled—both the ewes and rams were placed in a cooling chamber during day and turned to pasture at night.

The Control ewes were run continuously with rams in open fields with only a minimal amount of shade. The Cooled ewes were placed in a temperature control chamber consisting of an ammunition storage igloo or bunker equipped with artificial refrigeration to prevent temperatures above 75° F. The treatments continued for the equivalent of two estrual cycles after which both groups were turned together on pasture. Ewes had access to a dry roughage (sorghum hay) while in the chamber. Mating records were not kept on either group. The results are shown in Table 1. Differences between the two groups were not statistically significant.

TABLE 1. EFFECT OF COOLING AT MATING (12 HOURS DAILY FOR A PERIOD EQUIVALENT TO TWO ESTRUAL CYCLES BEGINNING JULY 1, 1967) ON REPRODUCTIVE PERFORMANCE OF MATURE RAMBOUILLET EWES

Treatment	Number ewes	Percent ewes lambing	Percent lambs born: Of ewes exposed	Percent lambs born: Of ewes lambing	Average lambing date
Control	49	81.6	104.1	127.5	Jan. 23, 1968
Cooled	51	80.4	109.8	136.6	Jan. 23, 1968

1968 Trial

The 1968 trial was similar to that conducted in 1967. Essentially the same ewes were used. The major difference between the two trials was that the cooling chamber was changed from mechanical refrigeration to evaporative cooling. The latter system proved to be more satisfactory in being simpler to maintain and in providing a more desirable atmosphere inside the chamber. Although temperatures were not always maintained at or below 75° F., control was adequate to prevent high temperature stress in the ewes. The results are shown in Table 2. Again treatment differences were not statistically significant. The average lambing date was approximately a month earlier, probably because the ewes were 1 year older and in better condition. This is shown somewhat by the improved performance of the ewes in all measures of reproduction efficiency.

Discussion

Although the reproductive performance of the ewes involved in these studies leaves something to be desired, especially in percent ewes lambing, there is no consistent evidence that high environmental temperatures in the range experienced in these studies are a major cause of embryo loss. In these studies, upward of 80 percent of the control ewes lambed from matings made in July and August, and, thus, any direct effect of temperature on reproduction would be marginal. These data compare favorably to what might be expected from mating at this time of the year from the standpoint of seasonal restriction. Neither of the individual trials nor the pooled results from the two yielded statistically significant differences between the treatments. However, it is of interest to note that such differences as do exist (6.9 percent lambs born from the combined results) favor the cooled ewes in both trials. The lack of statistical significance does not mean that these differences are not real, but only that with the numbers involved and the magnitude of differences observed, it is not possible to say that these differences are not due to chance. However, since it is known that high temperature stress conditions (less shade, more humidity and frequent high temperature) are more severe at the McGregor Center than in the plateau region where most of the sheep are grown, it seems reasonable to conclude that confining and artificial cooling of ewes during the breeding season is not justified in the majority of the flocks of Texas. However, certain precautions seem to be in order. Only fine-wool ewes (Rambouillet) were used in these studies, and different results probably would have been obtained if medium-wool ewes had been used or if environmental stress conditions had been more severe. The availability of good shade would appear to be important since it is known (Shelton, 1965) that good shade will do much to alleviate high temperature stress. Producers should exercise caution in moving or handling breeding ewes during times of high temperature stress. Death losses can result, and reproductive failures can occur as a result of high temperature stress induced by physical activity (Spies *et al.,* 1965).

TABLE 2. INFLUENCE OF COOLING AT MATING ON REPRODUCTIVE PERFORMANCE OF MATURE FINE-WOOL EWES, 1968

Treatment	Number ewes	Percent ewes lambing	Percent lambs born: Of ewes exposed	Percent lambs born: Of ewes lambing	Average lambing date
Control	53	86.8	118.9	136.9	Dec. 17, 1968
Cooled	48	89.6	127.0	141.8	Dec. 17, 1968

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PR-2733

Effect of Flurogestone Acetate On Estrous Response in Ewes

R. A. Orts, A. L. Hoermann, T. D. Deen, T. L. Woodward and A. M. Sorensen, Jr.

Synchronization of estrus in sheep has been successful through the use of progesterone or progesterone analogues. Studies which have employed intravaginal sponges impregnated with the progestogen flurogestone acetate have proven this compound's effectiveness in synchronizing estrus in both sheep and cattle. However, the time to onset and length of estrus have varied with the use of this progestogen.

The purpose of this investigation was to synchronize ewes with flurogestone acetate and determine whether initiation of synchronization is more advantageous at a particular stage of the estrous cycle and whether the time of withdrawal of the compound influences the degree of synchronization.

Experimental Procedure

Fifty-five Rambouillet ewes were used for this study. Thirty-six estrous ewes were divided into three groups of 14, 10 and 12 animals. Pessaries containing 20 mg flurogestone acetate were placed in the vagina of each animal at either 2, 9 or 14 days after observed estrus. The pessaries were left in place for 14 days.

The remaining 19 animals were not synchronized and served as controls.

TABLE 1. INCIDENCE OF ESTRUS WITHIN 5 DAYS FOLLOWING TREATMENT

Stage of cycle[1]	Number animals	Number in estrus after treatment	Percent synchronized within 5 days
2	14	11	78.6
9	10	9	90.0
14	12	11	91.7
Total	36	31	86.1

[1] Indicates day postestrus treatment began.

TABLE 2. ONSET OF ESTRUS FOLLOWING TREATMENT

Stage of cycle	Number animals	Day of onset					Number ewes exhibiting estrus after treatment	Percent synchronized ewes in estrus within		Percent total ewes in estrus within 3 days
		1	2	3	4	5 or more		2 days	3 days	
2	14	1	5	4	1	0	11	54.5	90.9	71.4
9	10	1	7	1	0	0	9	88.9	100	90.0
14	12	0	8	3	0	0	11	72.7	100	91.7
Total	36	2	20	8	1	0	31	71.0	96.8	83.3

TABLE 3. ONSET AND LENGTH OF ESTRUS FOLLOWING TREATMENT

Stage of cycle	Number animals observed	Number animals synchronized	Hours to onset	Length of estrus, hours
2	14	11	52.4	32.7
9	10	9	44.9	33.3
14	12	11	49.3	26.2
Control	19			36.0

Results

No animals lost pessaries during the treatment period; none showed signs of estrus while 86.1 percent of all animals treated were synchronized (Table 1). Animals which were synchronized on day 2 showed a lower percentage of synchronization than the other two groups.

The incidence of estrus among the treated animals within the 5-day observation period following pessary removal is summarized in Table 2. Although there is an apparent trend toward less synchronization in those animals treated on day 2 of the cycle, no statistically significant differences were found.

Table 3 shows the time to onset and length of synchronized estrus of the treated groups. Time to onset ranged from 44.9 hours for those treated on day 9 to 52.4 hours for those treated on day 2. The average time to onset was 48.8 hours. All treated animals had shorter estrous periods than control animals. No animals exhibited estrus for more than 2 days (Table 4). Within 24 hours after coming into estrus, 88.8 percent of the synchronized animals treated on day 14 were out of estrus as compared to 15.8 percent of the control animals.

TABLE 4. DURATION OF ESTRUS FOLLOWING TREATMENT

Stage of cycle	Number animals observed	Number exhibiting estrus	Number and percent ewes exhibiting estrus for	
			1 day	2 days
2	14	11	3 (27.3)	8 (72.7)
9	10	9	2 (33.3)	7 (66.7)
14	12	11	9 (88.8)	2 (11.2)
Total	36	31	14 (45.2)	17 (54.8)
Control	19	19	3 (15.8)	16 (84.2)

TABLE 5. HOURS TO ONSET OF ESTRUS RELATIVE TO TIME OF REMOVAL OF PESSARY

Stage of cycle	Time of withdrawal	
	AM	PM
2	58.8	47.
9	46.6	44.
14	47.0	50.
Total	51.5	47.3

TABLE 6. LENGTH OF ESTRUS (HOURS) RELATIVE TO TIME OF REMOVAL OF PESSARY

Stage of cycle	Time of withdrawal	
	AM	PM
2	36.0	30.0
9	32.0	34.0
14	24.0	27.4
Total	31.0	30.1

Tables 5 and 6 show that neither time to onset nor length of estrus was affected by the time of removal of the pessaries.

Acknowledgment

Grateful acknowledgment is expressed to G. D. Searle and Company for the flurogestone acetate impregnated pessaries.

PR-2734

Ovulation and Fertility in Ewes Synchronized With Flurogestone Acetate

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Progesterone and synthetic progestogens have been used successfully in synchronizing estrus in various animals. In most reported studies, synchronization was achieved successfully, but fertility was low.

The reason for lowered fertility after synchronized estrus is not known, nor is the reason for variations in fertility among synchronized animals. This investigation was undertaken to determine whether the initiation of synchronization at a particular stage of the estrous cycle would influence ovulation and fertility.

TABLE 1. OVULATION RESPONSE AND PERCENT OVA RECOVERED

Group[1]	Number ewes	Number corpora hemmorhagica	Number ova recovered	Percent recovered
2	10	12	6	50.0
9	9	9	8	88.8
14	11	14	9	64.3
C	19	23	13	56.5

[1] Indicates day of cycle when pessary was implanted, or control.

TABLE 2. FERTILITY OF RECOVERED OVA

Group	Number ewes	Number ova recovered	Number ova fertilized	Ova, percent fertilized
2	10	6	5	83.3
9	9	8	5	62.5
14	11	9	6	66.6
Total	30	23	16	69.6
Control	19	13	11	84.6

Experimental Procedure

Intravaginal pessaries impregnated with 20 milligrams flurogestone acetate were inserted into the vaginas of 36 Rambouillet ewes on day 2, 9 or 14 of the estrous cycle. Pessaries were kept in place for 14 days. Those animals coming into estrus within 3 days after pessary removal were then serviced. Nineteen ewes which were not synchronized served as controls.

The reproductive tracts were removed 2 to 4 days after breeding and were flushed to recover ova and determine whether fertilization had occurred. Ovaries were observed for corpora hemorrhagica.

Results

Recovery of ova from the tracts of synchronized animals ranged from 50 percent to 88.8 percent, while 56.5 percent recovery was made from the controls (Table 1). The group of animals which had received pessaries on day 9 of the cycle had a significantly higher recovery rate than day 2 animals.

The percent fertility of treated and control animals is shown in Table 2. All treated animals had a lower percentage of fertilized ova than control animals.

The percentages of animals yielding no ova, cleaved and/or uncleaved ova are presented in Table 3. No ova could be found in 60 percent of the animals from Group 2 compared to 11.1 percent in Group 9.

The data indicate that higher fertilization rate is achieved by synchronizing early in the cycle (Group 2) although fewer ova were recovered from these animals than from other treated animals.

Acknowledgment

Grateful acknowledgment is expressed to G. D. Searle and Company for the flurogestone acetate impregnated pessaries.

TABLE 3. NUMBERS OF EWES YIELDING CLEAVED, UNCLEAVED OR BOTH CLEAVED AND UNCLEAVED OVA

Group	Number ewes	Number and percent ewes yielding			
		No ova	Cleaved ova only	Uncleaved ova only	Both cleaved and uncleaved
2	10	6 (60.0)	3 (30.0)	0	1 (10.0)[1]
9	9	1 (11.1)	5 (55.6)	3 (33.3)	0
14	11	4 (36.4)	6 (54.5)	1 (9.1)	0
C	19	7 (36.8)	11 (57.9)	1 (5.3)	0

[1] One cleaved; one uncleaved.

PR-2735

Effect of Estrous Synchronization On the Histology of the Oviduct And Uterus of the Ewe

A. L. Hoermann, T. D. Deen, T. L. Woodward, R. A. Orts and A. M. Sorensen, Jr.

The use of progestational compounds for the purpose of synchronizing estrus in the ewe is of continuing interest. There is little problem in getting ewes to respond to treatment by injection, feeding or vaginal absorption of progestational compounds. A high percentage of ewes exhibit estrus within 1 to 3 days after removal of treatment. Length of this first estrus and the estrous cycle following appear to be normal. Conception rate at this synchronized estrus is generally reported to be quite low with normal conception rates reported at subsequent estrous periods. The objectives of this research were to determine the histological changes in the uterus and oviduct resulting from the use of flurogestone acetate and to relate these changes to conception.

Experimental Procedure

A group of 48 ewes was assigned to four treatment groups designated 2, 9, 14 and C. The numbers represent the day post estrus at which intravaginal pessaries were inserted, and C represents the control group allowed to cycle without treatment. Pessaries containing 20 mg flurogestone acetate were inserted into the anterior vagina and allowed to remain 14 days. Upon removal of the pessaries, the ewes were observed twice daily and bred each time estrus was exhibited.

An ovariohysterectomy by midventral laparotomy was performed 48 or 72 hours following the last service by a ram.

Sections of the uterus and the oviduct were fixed in a buffered formalin solution and then prepared for microscopic examination by standard procedures. Epithelial cell heights of the uterus and oviduct were measured at five locations in the tract, three in the oviduct and two in the uterine cornua. The data were analyzed by least squares treatment to determine significant differences.

Results

Oviduct and uterine epithelial cells at day 2 or day 3 following the last service by a ram in all treatment groups appeared to be near the same type and size as reported in the literature. Cell types at this stage of the estrous cycle were pseudostratified columnar, except for those found in sections of the oviduct near the tubouterine junction which were simple columnar.

Mean cell height for all animals was 24.8 microns with a range from 23.6 to 25.8 microns between treatment groups. The small variation found between animals and between treatment groups indicates that there is no significant difference in uterine or oviduct cell heights due to flurogestone acetate treatment. Therefore the secretory activity of these epithelial cells should be similar and the environment favorable for implantation and growth of the embryo.

Acknowledgment

Grateful acknowledgment is expressed to G. D. Searle and Company for the flurogestone acetate impregnated pessaries.

PR-2736

Influence of Estrous Synchronization On the Free Amino Acid Content In Ovine Cerviocovaginal Mucus

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Synchronization of estrus is a practical and economical means for concentrating the lambing season of ewes. It simplifies an artificial insemination program by bringing a large number of ewes into estrus during a few days, thus reducing the time required to inseminate the flock. Procedures have been developed to prevent estrus and ovulation, but mating at the post-treatment estrus has given conception rates lower than those obtained with untreated animals.

The solution to this problem may lie in understanding the physiological changes induced by the exogenous progestogen exerted upon the animal's system. Because sperm must travel through a major portion of the female tract before fertilizing the ovum, the physiological fluids through which it moves must be conducive to progress. The ovum likewise must have a medium favorable to its livelihood.

Experimental Procedure

Fifty-five mature Rambouillet ewes were assigned randomly to one control and three treatment groups. Pessaries (impregnated with 20 mg of 17α-acetoxy-9α-fluro-11β-hydroxyprogesterone) were inserted 2, 9 and 14 days following last standing estrus and were removed 14 days later. This procedure allowed for examining results from animals whose estrous cycles were interrupted at three different stages.

Cerviocovaginal mucus was collected from control ewes at their first standing estrus. That from treated ewes was collected at the first standing estrus following synchronization. The mucus was frozen and stored until analyses were made. The proteins were removed by adding a 10-percent sulfosalicylic acid solution and then centrifuging for 30 minutes at 35,000 rpm.

TABLE 1. MEANS FOR AMINO ACID CONCENTRATIONS IN CONTROL AND TREATED EWES

Treatment	Number of analyses	Micrograms per gram (mean)
Control	3	135.26
Group 2	3	94.45*
Group 9	3	66.85*
Group 14	3	39.40*

* Significantly lower than control values. ($P < .05$)

A Beckman model 120C amino acid analyzer was used to identify and quantitate 18 possible free amino acids.

Results and Discussion

A high percentage (86.1 percent) of the 36 ewes treated with the progestogen impregnated intravaginal sponges were synchronized. None of the ewes showed signs of estrus during the 14-day treatment period, and none of the pessaries was lost.

Thirty-three ninhydrin reacting compounds were recorded. Eighteen compounds were identified, but only 15 were quantitated.

Glycine and glutamic acid were the amino acids present in highest concentration in both treatment and control groups. The average values for all the amino acids, except lysine and alanine, were higher for control animals than for any of the treated groups.

A trend toward decreasing concentrations was established. The amino acid concentrations for those animals treated 2 days post estrus were lower than for controls, values for those animals treated on day 9 were lower than those treated on day 2 and those treated on day 14 had the lowest concentration (Table 1).

Two compounds with very basic pH values appeared in the mucus from control animals but not in mucus from the treated animals. The area under the peaks on the chromatogram indicated that large quantities of these two compounds were present.

An analysis of variance showed the decrease in amino acid concentrations of treated animals to be significant ($P < .05$).

The decrease in amino acid concentrations could have been caused by several factors. The pituitary-ovarian axis may have been disturbed causing a compensatory estrogen production after progestogen withdrawal, or the estrogen levels during treatment could also have been increased evoking increased secretion of cervical mucus.

Although no significant differences existed in conception rates for this experiment, it is obvious that the exogenous progestin is causing a change in the physiological fluids being secreted by the reproductive tract. These changes may be responsible for lowered conception rates.

Acknowledgment

Grateful acknowledgment is expressed to G. D. Searle and Company for the flurogestone acetate impregnated pessaries.

PR-2737

Feeding Lambs on a Raised Floor

Maurice Shelton and M. C. Calhoun

There has been considerable interest in recent years in the possible advantage of raising lambs, as well as other classes of livestock, on raised or slotted floors. The initial stimulus came from researchers involved in a study of parasitology who employed this means to produce lambs free of parasites. Since the initial work of parasitologists, the practice has been used to some extent by those producers involved in intense sheep management schemes. In Texas, the primary interest in the use of raised and slotted floors for lambs has been in connection with drylot fattening. The use of raised floors might be considered for preventing the animal from picking up internal parasites, increasing the comfort of the animal (especially in hot weather), reducing energy expenditure through exercise by close confinement or facilitating waste disposal.

Experimental Procedure

Several trials have been conducted at the McGregor Center to determine whether feeding lambs off the ground is beneficial. All these trials were conducted in the summer and fall, and all were conducted in experimental pens where the lambs had access to sheds for shade or shelter. Animals fed on raised floors were confined to sheltered areas throughout the study while control animals had access to a larger area outside the shed. In all trials except one, the animals were sheared when placed on feed. All animals were or had recently been treated with what was believed to be an effective anthelmintic (double dose of thiabenzole) when placed on test. In Trial 1, the lambs were fed on a heavy mesh screen wire placed approximately 8 inches above ground level. In the last three trials, the lambs were fed on floors made of expanded metal and placed 2 feet above ground level.

Results

The results are shown in Table 1. In only one of the four trials was there an advantage from feeding on a raised floor, and the summary of the four trials shows no advantage of experimental over control lambs. However, it should be pointed out that only under these conditions was no advantage realized, and it may not be in order to extend conclusions from these findings to other situations.

TABLE 1. SOME RESULTS OF FEEDING LAMBS ON RAISED FLOOR

	Trial 1		Trial 2		Trial 3		Trial 4		Summary	
	Control	Raised floor	Control	Raised floor	Control	Raised floor	Control	Raised floor	Control	Raised floor
Number lambs	12	12	11	11	10	10	11	10		
Dates of test	6/10-8/8/65		6/13-7/31/68		8/19-9/15/68		6/27-9/22/69			
Length of feeding period	60 days		48 days		27 days		87 days			
Type of fleece cover	Fresh shorn initially		Fresh shorn initially		½" wool growth initially		Fresh shorn initially			
Average daily gain	.393	.376	.499	.553	.441	.441	.484	.421	.454	.448
Daily feed intake	2.66	2.66	2.42	2.56	2.77	2.61	2.89	2.84	2.69	2.67
Feed per pound gain	6.77	7.07	4.86	4.63	6.29	5.92	5.98	6.75	5.98	6.09

1. Lambs in Trial 1 were fed pelleted feed on screen mesh floor approximately 8 inches above ground. All other trials were conducted with lambs receiving unpelleted rations on floors made of expanded metal placed 2 feet above ground. All trials were conducted with high concentrate rations of the following approximate compositions:

Dry rolled sorghum grain..............72.5 percent
Ground alfalfa hay....................12.0 percent
Cottonseed meal...................... 4.0 percent
Soybean meal......................... 4.0 percent
Molasses............................. 5.0 percent
Calcium carbonate............1.25 percent
Trace mineral salt............1.00 percent
Urea.........................0.50 percent
Aureomycin...................15 milligram per pound feed
Vitamin A....................1000 IU per pound feed

One possible reason for use of elevated floors is elimination of reinfestation with internal parasites. The primary means whereby sheep pick up internal parasites is generally thought to be through ingestion of infective larva with forage during grazing. However, it is increasingly evident that internal parasites, including the common species of gastro-intestinal nematodes, can be picked up in drylot. On two occasions, lambs have been lost at the McGregor Center from internal parasites known to have been picked up in drylot. The infrequency with which this occurs suggests that infestation in drylot occurs only under certain conditions. Included among these must be a depraved appetite resulting in eating of fecal material along with a specific set of moisture, temperature and humidity conditions which permit survival of larvae in the infective stage. An additional condition likely to be required is the presence of shaded areas which prevent the sterilizing effects of the sun. It is obvious from their performance that the control lambs did not pick up a heavy load of parasites during these studies. Another suggested reason for use of elevated floors is possible improvement of animal performance through lowering of temperature stress as a result of air movement under and around the animals. In Trial II, this use appeared to be beneficial to the animals, but this was not borne out in subsequent trials.

These studies provide no information on the effect of raised floors on efficiency of waste disposal. However, with lambs fed high energy rations in drylot, waste disposal is less a problem than with roughage rations.

PR-2738

Influence of Sex, Breed and Sire On Certain Carcass Traits of Lambs

MAURICE SHELTON AND Z. L. CARPENTER

Improvement in the type of lamb carcasses offered to the buying public has been a goal of the sheep industry for some time. Improvements may be made through environmental or management changes or through genetic progress. Improvements brought about through genetic means are much more permanent in nature and should be investigated as an opportunity for progress. The present analyses were undertaken primarily to examine the effects of breed and individuality of the sire on the important carcass traits.

Experimental Procedure

This study involved a total of 391 lambs produced on the McGregor Center in the years 1963-1967, inclusive, on which rather complete carcass and pedigree information was available. All the carcass data were collected at the Meats Laboratory at College Station. The numbers involved in certain analyses were somewhat reduced where individual items of data were incomplete. In most cases, the lambs were grown by running with their mothers on oat pasture. However, in some cases a period of drylot feeding was required to insure that the lambs were in slaughter condition. In general, all lambs received similar treatment within a given year, but management tended to vary widely between years. In comparison of breeds and sexes, the least squares procedure was used to obtain estimates of the effect of year, breed and sex. Carcass weight was included in least squares formula as a continuous variable, and all traits were adjusted to the mean carcass weight. Heritability estimates were obtained by paternal half-sib analysis. Year, sex and breed had a significant effect on essentially all traits studied, and thus all heritability analyses were made on a within-year, sex and breed basis. The numbers involved in the study and the resulting small sire groups tend to make the heritability estimates highly variable. This should be kept in mind in evaluating these estimates.

Results

The phenotypic correlations between selected carcass traits are shown in Table 1. These values generally are either of low magnitude or confirm previously established relationships. As expected, dressing percent, grade, fat thickness and total carcass value increased with carcass weight. Weight of the wholesale and retail cuts increased with carcass weight, but when these were expressed as a percent of carcass weight, they decreased with increasing carcass weight. The percent hindsaddle increased with weight, apparently largely a result of an increase in kidney fat which was weighed as a part of the hindsaddle. Loin eye area in square inches was positively correlated to carcass weight, but when expressed as a function of carcass weight (loin eye area per 50 pounds of carcass) tended to be negatively related to carcass weight or to various measures of fatness. In other words, one way to get a larger loin eye would be to slaughter larger animals, but this would be a desirable course of action only if larger carcasses could be produced without excess fattening. The high negative correlation between various measures of fatness and percent boneless retail cuts is expected both logically and mathematically since measures of fatness were used in predicting the latter. Tenderness as measured with the Warner-Bratzler shear, was not significantly related to any of the traits studied except USDA quality grade. This negative relationship indicates that the higher grading animals were more tender. However, this relationship (−.124) is of low magnitude.

The mean squares for the effects of years, sex, breed of sire and regression on carcass weight are shown in Table 2. The primary conclusion to be drawn from these data is that the environmental variables (year, sex and slaughter or carcass weight) are much more important than breed of sire as a source of variation in the carcass traits. Significant effects for breed of sire were obtained only in carcass weight per day of age, dressing percentage, both measures of wholesale and retail loin or loin eye area, fat thickness, fat trim, USDA grades and estimated boneless retail cuts. Except for the various measures involving the loin, all the variables on which significant breed effects were recorded are directly related to rate of growth or rate of fat deposition. This tends to confirm the previous suggestion that the quickest way to improve carcass desirability is through management and the next is through selection for rate of growth and later maturity or reduced rate of fat deposition at an early age. The least squares estimates of the effects of breeds, sex and regression on carcass weight are shown in Table 3. The effects of sex are large and important, but other studies have reported this finding, and they will not be treated in detail here. The male grouping in this study was a composite value representing both wethers and intact rams. The wethers were castrated at approximately 60 days. The slaughter age of the animals was generally 4 to 6 months. Although wethers and males did differ, the magnitude of these differences was small; therefore, data from both wethers and males were combined to give larger numbers in the sire-sex subgroups. Females tended to produce less desirable carcasses except for some advantage in tenderness. The increased weight of hindsaddle in females is apparently explained by increased weight of kidney fat. Because females fatten at an early age, it will continue to be necessary to slaughter at lighter weights than males unless a way to reduce their rate of fattening can be found.

Breed effects tended to be minor except in those factors associated with rate of growth or fattening. In respect to body proportions, significant breed effects were found only for those measures involving the loin. This appears to be due largely to the Dorsets which were at the top in loin eye area and had heavier wholesale and retail loins. Other breed differences were associated largely with rate of growth and fattening, and the magnitude of these differences, as well as the breed of choice, would vary greatly with slaughter weights. These data seem to suggest that choice of breeds would depend more on production efficiency than on the minor differences in carcass merit as reported here. Shelton and Bassett (1967) reported data on the influence of breed and individuality of sire on rate of growth from this same flock using much larger numbers. Rate of gain data favored the Suffolk, Hampshire and Columbia as sires—the differences being somewhat greater than shown here with the smaller numbers. Among the three breeds mentioned, the Hampshire-sired lambs fattened earlier than those lambs sired by Suffolk or Columbia rams (Table 3). This could be either an advantage or a disadvantage depending on the production system or intended slaughter weight. In this study, the Dorset sired lambs had some slight advantages in the carcass traits but not adequate to overcome their reduced market weights. Generally, sire effects were statistically nonsignificant. Those traits which yielded significant sire effects at the .01 level of probability include carcass weight per day of age, loin eye area, loin eye area per 50 pounds carcass weight and retail leg in percent. Those significant at the .05 level include fat trim in percent, retail leg in pounds, retail leg in percent, loin rack and shoulder in percent and USDA quality grade.

TABLE 1. PHENOTYPIC CORRELATIONS BETWEEN SELECTED CARCASS TRAITS[1]

	Dressing percent	Carcass weight per day age	Hindsaddle, percent	Foresaddle, percent	Loin eye area, square inches	Loin eye area per 50 pounds	Fat thickness, inches	USDA conformation grade	USDA final grade	Tenderness, shear	Retail loin, pound	Retail loin, percent	Retail leg, pound	Retail leg, percent	Kidney fat, percent	Other fat trim, percent	Carcass value per hundredweight	Estimated boneless retail cuts[2]
Carcass weight	.456	.439	.117	−.112	.576	−.237	.466	.429	.397	.014	.829	−.063	.829	−.203	.292	.324	−.038	−.255
Dressing percent		.227	.019	−.017	.422	.092	.413	.425	.391	.059	.391	−.021	.298	−.177	.166	.367	−.040	−.127
Weight per day age			.021	−.030	.254	−.078	.150	.128	.181	−.085	.268	−.215	.346	−.084	.166	.282	−.261	−.149
Hindsaddle, percent				−.992	.017	−.088	.116	.101	.138	−.058	.259	.299	.151	.039	.359	.166	.077	−.313
Foresaddle, percent					−.014	.087	−.113	−.093	−.124	.055	−.252	−.291	−.150	−.045	−.354	−.164	−.075	.322
Loin eye, inches						.637	.198	.466	.324	.043	.577	.141	.578	.017	−.017	−.010	.232	.117
Loin per 50 pounds							−.192	.161	.037	.032	−.080	.228	−.093	.187	−.277	−.297	.302	.363
Fat thickness, inches								.4[illegible]0	.468	.008	.365	−.060	.180	−.311	.290	.520	−.022	−.419
USDA conformation grade									.692	−.074	.481	.174	.293	−.138	.147	.261	.257	.080
USDA final grade										−.124	.389	.066	.173	−.236	.234	.377	.249	−.116
Tenderness											.010	−.013	.041	−.020	−.069	−.045	−.044	0.33
Retail loin, pounds												.492	.719	−.162	.157	.090	.251	−.087
Retail loin, percent													−.011	.020	−.166	−.330	.506	.231
Retail leg, pounds														.197	−.008	−.027	.140	.053
Retail leg, percent															−.344	−.611	.267	.358
Kidney fat, percent																.421	−.155	−.926
Other fat, percent																	−.387	−.447
Carcass value, per hundredweight																		.241

[1] Statistical significance is not indicated. Correlation values greater than .11 are significant at the .05 level, and values in excess of .14 are significant at the .01 level.
[2] Estimated boneless retail cuts were calculated by the following formula. Percent boneless major cuts = 47.7976 −11.7953 (single fat thickness, inches) +0.0916 (USDA conformation score) −0.4425 (kidney fat, percent).

TABLE 2. MEAN SQUARES OF YEARS, SEX, BREEDS AND REGRESSION ON CARCASS WEIGHT

Source	df	Carcass weight per day of age	Dressing percent	Hind-saddle, pounds	Hind-saddle, percent	Fore-saddle, pounds	Fore-saddle, percent	Wholesale loin, pounds	Wholesale loin, percent	Wholesale leg, pounds	Wholesale leg, percent
Years	5	.019**	300.5**	2.16**	10.79**	203.6	11.05**	4.80**	19.34**	2.50**	15.10**
Breeds	8	.016**	30.92**	.156	.726	44.77	.839	.708**	3.26**	.482	2.29
Sex	1	.021**	533.3**	22.51**	103.4**	47.82	100.2**	20.18**	89.55**	21.84**	105.8**
Regression on carcass weight	1	.160**	463.6**	1918.0**	4.10	3388.5**	3.71	285.4**	11.11**	286.0**	56.57**
Error	362	.002	5.56	.300	1.29	117.8	1.27	.192	.879	.303	1.33

Source	df	Retail loin, pounds	Retail loin, percent	Retail leg, pounds	Retail leg, percent	Loin eye area, square inches	Loin eye area per 50-pound carcass	Fat thickness, inches	Retail leg and loin, pounds	Retail leg and loin, percent
Years	5	31.80**	143.4**	2.95**	22.45**	.228**	.270*	.044**	38.21**	185.1*
Breeds	8	.759**	3.52**	.431	4.63	.213**	.251**	.012**	.669	7.71
Sex	1	2.26**	7.66**	23.04**	102.0**	.405**	.501**	.518**	11.88**	116.2**
Regression on carcass weight	1	171.4**	3.37	205.98**	68.08**	7.37**	1.44**	.389**	747.8**	197.7**
Error	362	.230	1.02	.264	2.99	.040	.051	.004	.566	6.40

Source	df	Retail shoulder percent	Tenderness shear	Fat trim, percent	USDA conformation grade	USDA final grade	Estimated boneless cuts, percent	Carcass value
Years	5	94.92**	509.1**	539.1**	12.29**	19.89**	8.26**	12.54**
Breeds	8	.830	8.97	7.15*	20.93**	6.56**	.359*	1.28
Sex	1	190.3**	49.50*	207.4**	46.66**	86.23**	23.73**	6.93**
Regression on carcass weight	1	23.27**	.005	150.60**	124.1**	90.63**	5.63**	1678.0**
Error	362	1.62	7.68	3.57	1.56	1.41	.172	1.02

TABLE 3. LEAST SQUARES ESTIMATES OF EFFECT OF BREED OF SIRE, SEX AND CARCASS WEIGHT ON SELECTED CARCASS TRAITS

	Number	Chilled carcass		Dressing, percent	Hind-saddle, percent	Fore-saddle, percent	Wholesale loin, percent	Retail loin, percent	Wholesale leg, percent	Retail leg, percent	Loin eye, square inches	Loin eye, square inches per 50 pounds	Oven broil shear	Fat thickness inches	Boneless retail cuts, percent	USDA conformation grade	USDA quality grade	Carcass value, dollars per hundredweight
		Actual pounds	Per day of age															
Breeds:																		
Rambouillet	49	43.32	.272	51.12	48.62	51.38	17.73	15.92	24.16	20.36	1.74	1.91	8.48	.186	48.17	10.32	10.02	55.36
Hampshire	135	46.40	.292	52.43	48.66	51.34	17.83	16.18	23.90	20.69	1.90	2.08	7.81	.201	48.36	11.85	10.87	55.77
Dorset	43	44.39	.273	53.66	48.62	51.41	18.54	16.79	23.69	20.00	1.91	2.11	7.82	.200	48.42	12.23	11.14	56.32
Suffolk	92	48.21	.284	51.47	48.57	51.43	17.93	16.05	24.21	20.94	1.92	2.11	7.43	.174	48.42	10.95	10.25	56.06
Columbia	49	45.54	.282	50.93	48.93	51.05	17.80	15.95	24.38	21.02	1.76	1.94	8.06	.173	48.27	10.57	10.31	55.54
Merino	7	41.07	.269	51.52	48.61	51.39	17.44	15.77	23.81	20.50	1.86	2.06	6.02	.164	48.23	10.15	10.08	54.65
Sex:																		
Males	234	45.45	.290	50.92	48.15	51.85	17.80	15.65	24.63	21.26	1.87	2.07	8.28	.154	48.55	10.47	9.88	55.99
Females	158	46.82	.278	53.46	49.32	50.69	18.10	16.74	23.45	20.16	1.80	1.99	7.50	.226	48.02	11.21	10.89	55.29
Regression on carcass weight				.230	.023	−.022	.038	−.020	−.086	−.088	.029	−.013	−.0002	.006	−.025	.119	.102	−.029

Heritability estimates calculated by paternal half-sib analyses are shown in Table 4. These estimates represent pooled values calculated within sex, year and breed. With the numbers involved in the study fragmented into the small subgroups as a result of these classifications, the resulting estimates are likely to be erratic. Thus, the reader is cautioned against interpreting these values as more than estimates. The method of calculating is based on a ratio of variance between sires as compared to variance within sires. Theoretically, heritability estimates are limited to the range of 0 to 1 or 0 to 100 if expressed in percent. However, due to the method of calculation, they are not so limited, and negative values or values in excess of one can very well occur as a result of random variation or experimental error. Thus, except for two, all estimates are positive and generally in the range of meaningful values. This would tend to indicate that, in general, the carcass traits are under hereditary control and subject to change through breeding. In general, traits which represent a measure of a single entity yield higher estimates than those which are composite or estimated values. For instance, carcass value, which gives emphasis to both yield of retail cuts and to quality grade which tend to be negatively related (Table 1), shows negative heritability.

Although these data suggest that it is possible to select for desirable carcass attributes, the breeder should be cautioned against being too optimistic. The major problems appear to be expense, time delay and lack of reach or selection differential. Even after carcass data on a representative sample of the offspring of several sires are collected, it is difficult to locate a sire distinctly superior in such traits as loin eye area or weight of loin or leg. Most major differences are related to rate of gain or to fat deposition. The economic importance of differences in such traits as rate of growth or slaughter weight dwarf in value the variations in weight of preferred cuts, and the former traits can be selected for on the live animal without the time or expense of progeny testing.

TABLE 4. SOME HERITABILITY ESTIMATES OBTAINED BY PATERNAL HALF-SIB ANALYSES (POOLED DATA)

Trait	Heritability, percent
Live slaughter weight	33.4
Dressing percent	24.8
Chilled carcass weight	12.6
Chilled carcass weight, per day age	63.3
Hindsaddle, percent	26.9
Foresaddle, percent	21.0
Wholesale loin, percent	25.8
Wholesale leg, percent	25.6
Retail loin, percent	6.2
Retail leg, pound	47.3
Retail leg and loin	12.1
Retail leg, loin, rack and shoulder	15.3
Loin eye area, square inches	91.4
Oven broil tenderness shear, pounds	20.9
Fat thickness (average of 6 measures in inches)	34.5
Boneless retail cuts, percent	6.8
USDA conformation grade	−16.0
USDA quality grade	52.3
Carcass value, dollars per hundredweight	−6.4

Literature Cited

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Prediction Equations for Estimating Lamb Carcass Cutability Under Commercial Conditions

H. W. KAMMLAH, G. C. SMITH AND Z. L. CARPENTER

Field, Kemp and Varney (1963) suggested that methods for quick and accurate estimation of the cutability of lamb carcasses should be developed. Such measures would be helpful in establishing more definitive objectives in production and would provide a simple, yet precise, index of carcass merit. The most practical approach in achieving estimates of carcass value involves the utilization of prediction equations. To best serve the needs of potential users, equations should be designed for use under commercial conditions. Equations requiring the removal and weighing of internal fats, as well as the exposure and measurement of the muscle and fat areas at the 12th rib have been proposed by Hoke (1961), Judge and Martin (1963), Spurlock and Bradford (1965), Judge, Martin and Outhouse (1966), Johnston *et al.* (1967), Carpenter *et al.* (1969), Oliver *et al.* (1968) and Field and Riley (1968). Such objectivity is seldom possible under commercial conditions because neither event occurs in the normal merchandising procedure. Consequently, equations should be devised which rely upon combinations of traits which could be used to achieve estimates of carcass cutability under a variety of data-collection conditions (Smith *et al.*, 1969).

The present investigation was designed to identify specific equations which could be used to accurately predict lamb carcass cutability under conditions of minimal carcass breakdown and processing requirements.

Experimental Procedure

Data were collected from 577 lamb carcasses which ranged in weight from 25.6 to 92.0 pounds and in USDA grade from high Prime to average Utility (USDA, 1969). A number of scores were assigned to the carcasses by either USDA or Texas A&M University personnel. Such scores included whole carcass, leg and body conformation, quality and final grade scores (USDA) and fat cover, side view, ribiness and estimated percent internal fat scores (TAMU). Acetate paper tracings were made of both *longissimus dorsi* (ribeye) muscles at the 12th rib and were measured and averaged to determine the area exposed. External fat thickness was determined at points (a) 1/4, (b) 1/2 and (c) 3/4 the length of the longitudinal axis of the *l. dorsi* and (d) at a point 2 inches lateral to the outer edge of the *l. dorsi.* A fat measure (e) opposite the center of the *l. dorsi* was obtained from the intact carcass using a swine backfat probe. These measurements were designated as follows: (c) as single fat measure; the mean of (a), (b) and (c) as average fat measure; (d) as body wall thickness; the mean of (a), (b), (c) and (d) as total fat measure and (e) as fat probe. The carcasses were processed into major retail cuts (leg, loin, rack and shoulder) according to the procedure of Carpenter *et al.* (1964) as modified by Smith *et al.* (1969).

In the present study, three sets of prediction equations were developed which could be used under varying commercial conditions to take maximum advantage of the potential data. One set of equations requires that carcasses be ribbed (split between the 12th and 13th ribs) and that internal fat be removed and weighed. The second set of equations also requires that carcasses be ribbed, but percent of internal fat would be estimated. The third group of equations could be used under conditions in which it is not possible to rib the carcasses or to remove internal fat. Such equations could conceivably be the only ones which are acceptable in a specific commercial plant.

Results and Discussion

Simple correlation coefficients (Table 1) indicate that all of the measurements studied, except ribeye area per hundred weight (area/cwt.), were negatively ($P<0.1$) related to percent of major retail cuts. A larger ribeye area/cwt. is associated with leaner, higher-yielding carcasses such that the higher the value for this trait the less trimmable fat present on a carcass. Whether this measurement truly reflects muscling or is merely an indirect measure of fatness, it would ultimately result in a greater proportion of retail cuts in the carcass. When actual ribeye area is considered rather than area/cwt., it is negatively ($P<0.1$) related to percent of retail cuts. Other researchers have reported correlation coefficients between actual ribeye area and measurements of the lean content of lamb carcasses ranging from 0.07 (Judge and Martin, 1964) to 0.82 Judge *et al.,* (1963).

All of the fat measurements in Table 1 are negatively ($P<.01$) related to percent retail cuts. This finding is in agreement with Carpenter *et al.* (1964) who found that as carcass weight, kidney fat or fat thickness over the 12th rib increased, there was an increase in trimmable fat which resulted in a decrease in the yield of retail cuts. Zinn (1961), Hiner and Thornton (1962), Judge and Martin (1963), Carpenter *et al.* (1964) and Judge *et al.* (1966) have also reported significant negative relationships between measurements of fat thickness at the 12th rib and retail yields. As the amount of external fat cover or volume of internal fat in the carcass increases, the percent of retail cuts will decrease. This is supported by Rouse *et al.* (1968) who reported that, in growing lambs, the percent lean remained rather constant while percent fat increased and percent bone decreased.

Simple correlation coefficients (Table 2) indicate that visual scores were negatively ($P<.01$) related to the percent of retail cuts. Higher scores for side view or ribiness are associated with carcasses exhibiting extreme depth and width of the ribcage. Such changes result in decreased proportions of major retail cuts in the carcass as a result of the increase in breast and plate percentages.

TABLE 1. SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS MEASUREMENTS AND RETAIL CUT YIELDS

Trait	df	Major retail cuts, percent
Carcass weight	575	− .42**
Internal fat weight	575	− .73**
Internal fat, percent	575	− .75**
Area of ribeye	575	− .17**
Ribeye area/cwt. carcass	575	0.42**
Single fat measure	575	− .84**
Single fat measure/cwt. carcass	575	− .77**
Average fat measure	575	− .86**
Average fat measure/cwt. carcass	575	− .79**
Body wall thickness	575	− .81**
Body wall thickness/cwt. carcass	575	− .68**
Total fat measure	575	− .86**
Total fat measure/cwt. carcass	575	− .78**
Fat probe	575	− .85**
Fat probe/cwt. carcass	575	− .78**

**P <.01.
*P <.05.

TABLE 2. SIMPLE CORRELATION COEFFICIENTS BETWEEN VISUAL CARCASS SCORES AND RETAIL CUT YIELDS

Trait[1]	df	Major retail cuts, percent
Leg conformation score (USDA)	373	−.44**
Body conformation score (USDA)	373	−.48**
Whole carcass conformation score (USDA)	575	−.42**
Quality score (USDA)	575	−.49**
Final grade (USDA)	575	−.51**
Estimated percent internal fat (TAMU)	373	−.74**
Fat cover score (TAMU)	373	−.74**
Side view score (TAMU)	373	−.32**
Ribiness score (TAMU)	373	−.14**

**P <.01.
*P <.05.

[1] All traits designated (USDA) were assigned by USDA personnel on the third day post-slaughter. Those designated (TAMU) were assigned by University researchers on the 5th day following slaughter.

Conformation scores were negatively (P<.01) correlated with the percent of major retail cuts. Hoke (1961) reported slight increases in yield as conformation score increased while both Johnston *et al.* (1967) and Carpenter *et al.* (1969) reported a very low relationship between carcass conformation score and retail cut yield. USDA scroes for both quality and final grade are negatively (P<.01) correlated with percent of retail cuts. Wilford and Garrigus (1952) reported that as carcass grade increased, the proportion of lean and bone decreased, while fat increased.

Estimated percent internal fat and fat cover scores were negatively (P<.01) correlated with percent of lean primal cuts. Hammond (1932), Hirzel (1939), Callow (1948) and Wilford and Garrigus (1952) have recognized that the amount and distribution of fat is the major variable influencing lamb carcass composition. While total fat trim is the most accurate and informative measure, fat depth measurements are simple and highly related to retail cut yields.

The prediction equations in Tables 3 through 5 indicate that carcass weight, amount of internal fat and fat thickness measures were the most important traits for predicting percent major retail cuts. Carcass weight makes the greatest contribution to those equations which employ weight of internal fat and total fat measure (equations 2 and 3). Carcass weight is less important if actual ribeye area is among the traits included in the equation (equations 4 and 6) and is not essential to obtain 80 percent predictive accuracy (equation 9). If body wall thickness is used as an index of fatness, for example, equations 6 and 7, either carcass weight or ribeye area is a necessary component in the equations.

Some measure of the volume of internal fat (kidney and pelvic regions) is essential for obtaining accuracy in cutability equations. It is of little concern whether internal fat is estimated or removed and weighed (for example, equations 2 versus 4) if the

TABLE 3. REGRESSION EQUATIONS FOR PREDICTING PERCENT OF RETAIL CUTS WITH MAXIMUM ACCURACY USING RIBBED CARCASSES AND ACTUAL WEIGHTS OF INTERNAL FAT

Equation Dependent variable Intercept (constant)		1 Percent 75.0640	2 Percent 64.2370	3 Percent 64.5367
Carcass weight,	b	− .0882	0.1267	0.1451
pounds	b′	− .24**	0.35**	0.40**
Internal fat weight,	b		− 1.6539	− 1.6999
pounds	b′		− .43**	− .44**
Internal fat, percent	b	− 1.0091		
	b′	− .35**		
Total fat measure,	b		−24.4231	−24.5350
inches	b′		− .79**	− .79**
Total fat measure,	b	−11.8836		
per hundredweight	b′	− .59**		
Ribeye area, square	b		0.5675	
inches	b′		0.05**	
Ribeye area, per				
hundredweight	b	0.3592		
carcass, square	b′	0.05**		
inches				
R^2 x 100		84.44	83.20	83.12
R		0.919	0.912	0.912
SEE		1.6356	1.6995	1.7024

**P <.01.
*P <.05.

TABLE 4. REGRESSION EQUATIONS FOR PREDICTING PERCENT OF RETAIL CUTS WITH MAXIMUM ACCURACY USING RIBBED CARCASSES AND ESTIMATED PERCENTAGES OF INTERNAL FAT

Equation Dependent variable Intercept (constant)		4 Percent 66.8613	5 Percent 72.8632	6 Percent 67.0160
Carcass weight,	b	0.0385	− .0777	0.0179
pounds	b′	0.11**	− .22**	− .05*
Estimated internal fat,	b	− .7859	− .8318	− .8805
percent	b′	− .28**	− .29**	− .31**
Total fat measure,	b	−24.5387		
inches	b′	− .80**		
Total fat measure				
per hundredweight	b		−12.4355	
carcass, inches	b′		− .60**	
Body wall thickness,	b			−13.6455
inches	b′			− .80**
Ribeye area, square	b	1.3965		3.0874
inches	b′	0.12**		0.27**
Ribeye area per				
hundredweight	b		0.7094	
carcass, square	b′		0.10**	
inches				
R^2 x 100		83.84	82.86	82.39
R		0.916	0.910	0.908
SEE		1.7254	1.7765	1.8008

**P <.01.
*P <.05.

TABLE 5. REGRESSION EQUATIONS FOR PREDICTING PERCENT OF RETAIL CUTS WITH MAXIMUM ACCURACY USING PHYSICALLY INTACT CARCASSES

Equation Dependent variable Intercept (constant)		7 Percent 69.6790	8 Percent 68.0813	9 Percent 68.1648
Carcass weight,	b	0.0884	0.0360	
pounds	b′	0.25**	0.10**	
Estimated internal fat,	b	− .8814	− .9168	− .8642
percent	b′	− .31**	− .32**	− .31**
Body wall thickness,	b	−10.9766		
inches	b′	− .64**		
Fat probe, inches	b		−23.6716	−22.4024
	b′		− .58**	− .55**
Leg conformation	b			0.1316
score[1]	b′			0.05**
Fat cover score[2]	b	− .4439	− .3313	− .3551
	b′	− .22**	− .16**	− .17**
R^2 x 100		81.76	81.00	80.44
R		0.904	0.900	0.897
SEE		1.8329	1.8709	1.8979

[1] High Prime = 15, average Prime = 14........low Cull = 1.
[2] Photographic standard: 9 is very completely covered with fat while 1 is decidedly underfinished.
**P <.01.
*P <.05.

subjective estimates are reasonably accurate. Internal fat is an important criterion in determining cutability because of the extreme variability displayed among carcasses (the range observed in the present study was from 1 to 12 percent of the carcass weight).

Consideration of the respective b′ values (standard partial regression coefficients) in equation 4 indicates that fat thickness is approximately 7, 3 and 6 times as important as carcass weight, estimated percent internal fat and ribeye area, respectively, in explaining the variation in retail cut percentages. Total fat measure (an average of eight measurements from the ribbed carcass) was more closely related to cutability than were average fat, single fat or fat probe measurements. Smith *et al.* (1969) reported that the more individual estimates of fat thickness incorporated into the fat measure, the more accurate the equation will be for predicting percent retail cuts.

Carpenter *et al.* (1964) and Judge *et al.* (1963) have suggested that ribeye area is a fairly accurate measure of muscling in carcasses of a narrow weight range, but that it adds little to the predictive value if reliable measures of fatness are available. Ribeye area was significantly ($P<.01$) related to predictive accuracy in all of the equations in which it was used (equations 1, 2, 4, 5 and 6) but its actual contribution was low.

Judge *et al.* (1966) reported that, since the time available for collection of carcass data under commercial conditions is limited, simple procedures for evaluating large numbers of carcasses are desirable. Equations for predicting primal cut yields from intact carcasses are presented in Table 5. When both predictive accuracy and ease of measurement were considered, the most practical combination of traits for predicting carcass yields included carcass weight, body wall thickness, estimated percent of internal fat and a subjective fat cover score (equation 9). Leg conformation score appears as an independent variable in equation 9, and though significant ($P<.01$), it is of much less value than measures of fatness in predicting cutability. Spurlock *et al.* (1966), Johnston *et al.* (1967) and Field and Riley (1968) reported that such scores contributed very little to the accuracy of equations for estimating lamb carcass composition. Standards prepared by the USDA for yield grading lamb carcasses employ leg conformation as a predictor of muscling (USDA, 1969).

Fat cover score made a significant ($P<.01$) contribution to all of the equations in which it was used and appears among the best subsets of independent variables for predicting percent major retail cuts (equation 9). Equation 9 appears to be an extremely valuable tool for lamb carcass comparisons, since it is only 2.7 percent less accurate than equation 1 (Table 3) while requiring considerably less time and essentially no change in the physical form of the carcass.

In general, equations employing carcass weight, internal fat weight or percent and fat thickness measurements, where the latter two traits are either measured or estimated, provide sufficient accuracy when properly weighted to predict percent of lean primal cuts with greater than 80 percent accuracy.

Summary and Conclusions

Closely trimmed retail cuts from 577 carcasses were utilized for the development of prediction equations for use under varying commercial conditions. Nine equations were selected to achieve maximum accuracy for prescribed data-collection conditions. Simple correlation coefficients of approximately −.74 and −.85 between measures of internal fat deposition and fat thickness over the ribeye, respectively, evidenced the profound influence of excessive fatness on percent of retail cuts. Ribeye area contributed little to prediction equations unless body wall thickness (singly or combined) was used as the fatness index. The most accurate equations for predicting percent of trimmed retail cuts consisted of measures of carcass weight, internal fat, total fat thickness and ribeye area. However, a combination of traits including carcass weight, estimated percent of internal fat, body wall thickness and fat cover score did not require that the carcass be ribbed yet was nearly as accurate. In general, equations employing carcass weight, internal fat weight or percent and fat thickness measurements, where the latter two traits are either measured or estimated, can be expected to predict percent of major retail cuts with greater than 80 percent accuracy.

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PR-2740

Accuracy of Prediction Equations For Estimating Lamb Carcass Cutability Within Narrow Ranges of Weight And Fat Thickness

H. W. Kammlah, G. C. Smith and Z. L. Carpenter

Amount and distribution of fat is the major variable influencing lamb carcass composition. Strong negative relationships between external fat thickness and carcass retail yields have been reported by Spurlock and Bradford (1965), Judge *et al.* (1966), Oliver (1967) and Smith *et al.* (1969). Increased area of ribeye is positively related to cutability (Hoke, 1961; Field *et al.*, 1963; Spurlock *et al.* 1966) but is only a fair measure of muscling in carcasses of a narrow weight range (Carpenter *et al.*, 1964; Judge *et al.*, 1963) and thus adds little to prediction equations if reliable measures of fatness are available. Smith *et al.* (1969) reported that it was possible to predict the percent of major retail cuts with approximately 80 percent accuracy without using carcass weight as an independent variable.

Most of the prediction equations which have been reported by previous investigators were derived from populations of carcasses exhibiting wide ranges in weight and external fat thickness (Field, Kemp and Varney, 1963; Carpenter *et al.*, 1964; Johnston *et al.*, 1967; Field and Riley, 1968; Carpenter *et al.*, 1969; Riley *et al.*, 1969; and Smith *et al.*, 1969). Conversely, most of the carcasses exhibited in lamb carcass contests are strikingly similar in weight, muscling and fatness characteristics.

The present study represents an attempt to identify prediction equations which would be accurate within populations of lamb carcasses exhibiting narrow ranges in weight and/or fatness.

Experimental Procedure

Cutability data collected from 577 carcasses were utilized in this study. These carcasses exhibited ranges in external fat thickness from 0.02 to 0.69 inches and in carcass weight from 25 to 92 pounds. Similar variations are not encountered under normal lamb carcass contest conditions. Correspondingly, the data were initially subdivided into groups based on narrow ranges of carcass weight and subsequently into groups with narrow ranges in subcutaneous fat thickness. The nine equations selected as being most accurate under specific data-collection conditions (Kammlah *et al.*, 1970) were used within each weight or fat thickness group to determine their accuracy in predicting cutability.

Results and Discussion

Means, standard deviations and coefficients of variation for the complete population of carcasses are included in Table 1.

Coefficients of variation (Table 1) indicate that measures of fatness exhibited considerable variability, with internal fat weight being the most variable trait studied (CV = 49.59). Measures of muscling such as conformation scores and ribeye area were less variable than those for fatness characteristics. Rouse *et al.* (1968) reported that, during growth, the amount of

TABLE 1. MEANS, STANDARD DEVIATION (SD) AND COEFFICIENTS OF VARIATION (CV) FOR LAMB CARCASS YIELDS, SCORES AND MEASUREMENTS

Variable	n	Mean	SD	CV
Estimated percent internal fat	375	4.31	1.51	34.99
Carcass weight, pounds	577	50.48	11.35	22.50
Retail cuts weight, pounds	577	10.41	2.23	21.43
Percent retail cuts	577	59.39	4.13	6.96
Internal fat weight, pounds	577	2.14	1.06	49.59
Percent internal fat	577	4.12	1.42	34.55
Area of ribeye, square inches	577	1.92	0.37	19.02
Single fat measure, inches	577	0.22	0.11	48.45
Average fat measure, inches	577	0.22	0.11	48.63
Body wall thickness, inches	577	0.79	0.24	30.37
Total fat measure, inches	577	0.37	0.13	36.99
Fat probe, inches	577	0.20	0.10	48.56

TABLE 2. COEFFICIENTS OF DETERMINATION (CD) FOR PREDICTION EQUATIONS WITH SELECTED FAT THICKNESS RANGES

Fat thickness range, (inches)	n	Range number	Equation 1	2	3	4	5	6	7	8	9
.02 to .69	577		84.44	83.20	83.12	83.84	82.86	82.39	81.76	81.00	80.44
Group 1											
.05 to .15	122	1	36.40	37.66	37.50	44.56	43.52	38.56	38.33	37.37	35.61
.05 to .20	192	2	54.38	55.50	55.44	52.18	51.98	46.89	47.24	48.79	48.03
.05 to .25	242	3	64.49	65.58	65.43	61.86	60.96	56.60	57.37	58.50	57.62
.05 to .30	302	4	74.09	74.78	74.57	71.75	70.55	68.70	68.53	68.15	66.99
.05 to .35	325	5	77.89	78.51	78.31	75.92	74.64	73.32	72.60	72.31	71.16
Group 2											
.10 to .20	166	6	45.42	46.80	46.51	43.93	44.15	41.03	40.06	39.30	37.45
.10 to .25	212	7	58.48	59.97	59.51	55.95	55.06	51.98	51.54	51.34	49.66
.10 to .30	272	8	70.53	71.57	71.13	68.27	66.90	66.12	64.84	63.45	61.74
.10 to .35	295	9	75.15	76.14	75.76	73.25	71.78	71.38	69.62	68.55	66.96
Group 3											
.15 to .25	139	10	51.61	55.62	55.21	40.25	37.93	39.85	40.88	36.18	34.88
.15 to .30	199	11	64.89	67.88	67.15	58.08	55.14	58.29	57.09	51.97	49.68
.15 to .35	222	12	70.36	73.13	72.58	65.14	62.14	65.01	62.87	58.87	56.65
Group 4											
.20 to .30	119	13	55.59	58.40	55.40	45.06	40.59	47.90	44.12	37.16	34.94
.20 to .35	142	14	61.73	64.96	63.00	54.02	49.45	56.17	50.44	44.80	42.53

lean remains rather constant while percent fat increases and percent bone decreases. For this population (Table 1), the CV value for weight of retail cuts was approximately three times as large as that for percent retail cuts. This may result from the decrease in variation which occurs when weights of cuts are converted to percentages, thereby removing some of the variation due to differences in carcass weight (Oliver *et al.* 1968). Attempts to estimate percent retail cuts are less efficient than predicting weight of retail cuts because it is more difficult to estimate that portion of variation which remains after computing percentages.

Coefficients of determination (CD) for prediction equations within selected fat thickness ranges, presented in Table 2, are comparatively low. The CD values for equations which encompass narrow fat ranges such as 0.05 to 0.15 inches or 0.10 to 0.20 inches are lower than those for equations which encompass wider fat ranges (0.10 to 0.35 inches or 0.15 to 0.35 inches). The CD values ranged from 35.61 to 44.56 for fat thickness ranges from 0.05 to 0.15 inches and from 66.96 to 76.14 for carcasses with a range in fat thickness from 0.10 to 0.35 inches. The highest CD value (Table 1) for each of the nine equations studied occurred in the same population (0.05 to 0.35 inches) which was the widest fat thickness range studied. The lowest CD values (Table 2) for each of the nine equations occurred in the same fat thickness range (0.05 - 0.15 inches). This is one of the narrowest ranges in fat thickness in this study and encompasses those carcasses having the least amount of fat cover in the population. CD values become progressively larger from range 1, group 1 to range 13, group 4 (or when moving from leaner to fatter carcasses) samples with ranges of 0.10 inches in fat thickness.

The lower CD values observed in group 1, which contains the leaner carcasses, compared to the higher CD values in group 4, which contains the fatter carcasses, indicate the importance of variations in fat measurements for purposes of predictive accuracy. One indication of the variability of fat content in different lamb carcasses can be observed when comparing the amount of external with that of internal fat. Lamb carcasses which have small amounts of external fat cover could be expected to have a small amount of internal fat. However, this is not always the case since amount of fat observed on the exterior of a carcass is not always an absolute indication of the amount of internal fat.

The low CD values displayed within narrow fat ranges indicate that there is very little difference in cutability between carcasses that are similar in fat thickness measurements. Groups of carcasses in which fat measurements are similar are difficult to rank according to cutability using equations in Table 2. It might be more accurate, though more subjective, to evaluate cutability differences using visual characteristics.

Table 3 contains coefficients of determination for prediction equations within selected ranges in carcass weight. These coefficients of determination values were as much as 45 percent higher than those for fat thickness ranges in Table 2. This results from the greater amount of variation in fat thickness of carcasses in the selected weight range groups than was evident within fat thickness ranges in Table 2. Fat measurements are

TABLE 3. COEFFICIENTS OF DETERMINATION (CD) FOR PREDICTION EQUATIONS WITHIN SELECTED CARCASS WEIGHT RANGES

Carcass weight range, pounds	n	Equation 1	2	3	4	5	6	7	8	9
25.7 to 92.0	577	84.44	83.20	83.12	83.84	82.86	82.39	81.76	81.00	80.44
40.0 to 44.9	67	74.57	73.89	73.79	70.60	60.81	63.61	66.41	71.79	71.41
40.0 to 49.9	147	81.27	81.63	81.63	79.03	78.71	72.70	73.68	76.99	77.01
40.0 to 54.9	194	82.99	83.16	83.15	81.48	80.99	76.03	75.68	78.02	78.18
45.0 to 49.9	80	88.10	88.10	88.10	85.90	85.98	79.73	80.80	81.37	81.60
45.0 to 54.9	127	87.69	87.43	87.43	86.56	86.54	81.90	81.83	80.80	81.22
45.0 to 59.9	161	87.05	86.93	86.85	84.83	84.53	82.19	80.93	78.71	79.03
45.0 to 64.9	188	86.46	86.22	86.14	83.09	82.87	82.14	81.86	78.20	78.36
45.0 to 69.9	214	86.63	86.37	86.29	82.71	82.29	82.27	80.84	78.16	78.19
50.0 to 54.9	47	87.46	87.46	87.45	87.60	87.50	85.30	84.67	80.58	81.53
50.0 to 59.9	81	86.22	86.55	86.27	84.15	83.76	84.00	82.27	76.23	76.11
50.0 to 64.9	111	85.35	85.49	85.22	80.73	80.56	83.68	83.01	75.78	75.83
50.0 to 69.9	134	85.77	85.89	85.74	80.76	80.49	83.34	81.59	75.76	75.45
55.0 to 59.9	34	87.46	87.81	85.58	81.41	81.19	85.54	81.57	72.61	72.46

important components of prediction equations, and the greater the variation in fat thickness or volume measurements, the more accurate the equation will be in determining differences in cutability. Measures of fat thickness were generally highly related to fat trim yields, Carpenter *et al.* (1969). Hammond (1932) reported that lean and bone are present in a constant relationship in lamb carcasses, while fatty tissue is the major variable. Matthews *et al.* (1959) reported that cross sectional measurements of the ribeye muscle were not as highly correlated to percent of wholesale cuts as were fat measurements. Hirzel (1939), Callow (1948) and Wilford and Garrigus (1952) have recognized that the amount and distribution of fat is the major variable influencing lamb carcass cutability.

The weight range of the total population of carcasses was from 25.0 to 92.0 pounds. The highest CD value was observed for the equation which included the total population (84.44; equation 1). CD values for different weight groups ranged from a high of 88.10 to a low of 60.81. This former value represents an increase in predictive accuracy of 3.5 percent over the equation for the total population and occurred in the weight group ranging from 45.0 to 49.9 pounds. Decreases in the variation of carcass weight were most probably accompanied by a decrease in other factors including amount or percent of internal fat, fat thickness measurements and ribeye area. As previously stated, the greater the variability in fatness measurements observed, the more accurate the equation will be. However, the limited number of carcasses involved (n - 80) may have resulted in an increase in predictive accuracy.

Summary and Conclusions

In the present study attempts were made to select prediction equations for estimating cutability which would be accurate within narrow ranges of weight and fat thickness. The coefficients of determination were greatly reduced within populations with little variability in fat thickness, especially in those with very narrow fat thickness ranges. This resulted from the decrease in variation in fat thickness measurements which occurs in carcass groups with small fat thickness ranges. The CD values were increased for several of the carcass weight ranges. However, this may have been due to a smaller number of carcasses in these specific ranges. Most of the CD values for narrow ranges in carcass weight were within the 80-percent range of accuracy which is not a significant decrease in comparison to the CD values for the entire population.

It is evident that prediction equations developed from carcasses with large ranges in weight and fat thickness are not accurate when applied to populations with greater homogeneity in cutability indicators.

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PR-2741

Accuracy of the USDA Yield Grades For Predicting Lamb Carcass Cutability

G. C. Smith, Z. L. Carpenter and G. T. King

Equations for predicting the cutability of ovine carcasses have been reported by Botkin *et al.* (1961), Hoke (1961), Hiner and Thornton (1962), Field, Kemp and Varney (1963), Judge and Martin (1963), Carpenter *et al.* (1964), Smith and Galgan (1964), Spurlock and Bradford (1965), Judge, Martin and Outhouse (1966), Spurlock, Bradford and Wheat (1966), Carpenter *et al.* (1966), Johnston *et al.* (1967), Oliver (1967) and Carpenter *et al.* (1969). Since Spurlock and Bradford (1965) compared the accuracy of six of these prediction equations, several new indices of carcass composition have been proposed (for example, body wall thickness, Carpenter *et al.*, 1964; the fat probe, Field and Riley, 1968; and fat cover score, Johnston *et al.*, 1967). Furthermore, a yield grading system for lamb carcasses which incorporates subjective estimates of fatness has been made available to the industry (USDA, 1969). The present investigation was designed to determine the accuracy of the USDA (1969) yield grading equation in comparison to that of previously reported equations for predicting the cutability of lamb carcasses.

Experimental Procedure

Cutability data were obtained from 577 ovine carcasses (wethers and ewes) which ranged in weight from 25.6 to 92.0 pounds and in grade from high Prime to average Utility (USDA standards). Breed, previous nutritional status and age were not available for this population of carcasses. All of the carcasses were assigned scores for conformation, maturity, overall quality and final grade. Each carcass was processed into retail cuts according to the procedure of Smith *et al.* (1969), in which all external fat in excess of 0.10 inches was removed.

Scores and measurements employed in each of the prediction equations were assigned by either USDA or University personnel. The data obtained from the present study were fitted into 10 previously reported prediction equations, and the resultant Y values were correlated with the actual yields of lean primal cuts for each carcass. The equations employed in the comparison were as follows:

Hoke (1961): Combined yield of trimmed retail cuts = 74.27 + 0.19 (conformation grade, 1 to 15) −0.546 (single fat thickness over the *l. dorsi*, mm.) −0.849 (percent kidney fat).

Field *et al.* (1963): Percent lean in the carcass = 33.27 + 3.90 (area of *l. dorsi*/45 lb. of carcass, in.) −0.46 fat thickness over *l. dorsi*, mm.) −0.80 (percent kidney and kidney fat) + 0.53 (percent untrimmed leg).

Judge and Martin (1963): percent edible portion = 87.76 −16.586 (fat thickness, in.) −2.048 (kidney fat, lb.) −0.270 (chilled carcass weight, lb.).

Spurlock and Bradford (1965): Percent trimmed cuts = 86.82 −0.234 (carcass weight, lb.) −0.847 (single fat depth, mm.) −1.479 (percent kidney fat).

Judge *et al.* (1966): Percent edible portion = 88.65 —16.15 (average of six fat thickness measures, cm.) −5.28 (kidney and kidney knob weight, kg.) −1.39 (leg plus loin weight, kg.) −.81 (body wall thickness, cm.).

Johnston *et al.* (1967): Total boneless cuts, percent = 70.38 + 0.13 (*l. dorsi* area, $cm.^2$) −.07 (carcass wt., kg.) −1.56 (percent kidney knob) −0.90 (finish group score).

Oliver (1967): Total consumer cuts, lb. = 4.65 + .83 (chilled carcass wt., lb.) −3.34 (body wall thickness, in.) −.73 (kidney fat weight, lb.).

Field and Riley (1968): Percent yield of major semi-boneless retail cuts from the leg, loin, rack and shoulder = 63.249 −.3147 (body wall thickness, mm.)

−.378 (fat depth ¾ across *l. dorsi*, mm.) −.580 (kidney fat wt., kg.).

Carpenter *et al.* (1969) Pounds of retail leg, loin, rack and shoulder = 3.753 + .597 (carcass wt., lb.) + .061 (carcass conformation) −6.889 (single fat thickness, in.) −.908 (kidney fat lb.).

USDA (1969) Yield Grade = 1.66 −(0.05 x leg conformation score) + (0.25 x percentage kidney and pelvic fat) + (6.66 x adjusted fat thickness over the *l. dorsi*, inches).

The equations of Oliver (1967) and Carpenter *et al.* (1969) were divided by carcass weight to achieve estimates of yields on a percent basis to make them more comparable with the other equations listed.

Results and Discussion

The ultimate merit of an individual lamb carcass results from observed differences in two value-determining characteristics: (a) quality characteristics of the lean (as a measure of expected palatability) and (b) the combined yield of retail cuts which can be obtained from the carcass (USDA, 1968). USDA grading standards for quality characteristics have been in effect since 1931 and have contributed to the recognition of differences among lambs at the market level. During the last several years, extensive research has been conducted by the USDA, several land-grant universities and the lamb industry on lamb carcass cutability. These latter studies suggested that carcasses of the same weight and quality grade could differ widely (12 percent; USDA, 1969) in yields of retail cuts from the leg, loin, rack and shoulder.

Differences in cutability result primarily from differences in fatness on the outside of the carcass, in the amount of fat deposited in the kidney and pelvic regions and in the amount of inherent muscling. Changes in cutability are associated with differences as large as $13 per hundredweight in total retail value between the highest and lowest yielding carcasses within the Choice grade (USDA, 1969). Once such differences were recognized, it was of critical concern to formulate a simple, yet accurate system for yield grading which could be used under commercial conditions to recognize merit among lamb carcasses. Although numerous researchers had formulated equations designed to estimate cutability, the USDA (in cooperation with the Texas Agricultural Experiment Station) developed an equation which, because of its simplicity, was more suitable for application under routine conditions in the packing plant.

Data from the 577 carcasses processed in the present study were used to evaluate a number of the prediction equations which have been reported as indices of lamb cutability. Spurlock and Bradford (1965) compared six regression equations and found those proposed by Hoke (1961), Field *et al.* (1963) and Judge *et al.* (1963) to be most satisfactory. The number of equations which have been added to the literature since 1965 justify a more current evaluation of existing equations. Furthermore, it would be of considerable interest to relate these regression equations to the endpoint of very closely trimmed primal cuts, which were used in the present investigation. Spurlock *et al.* (1966) recommended 0.08 to 0.16 inches as the preferred fat thickness over the l. *dorsi* for lamb carcasses of "high merit"; thus the processed carcasses in the present study conform to the "preferred" specifications of that report.

The apparent validity of the Hoke (1961), Field *et al.* (1963) and Judge and Martin (1963) prediction equations is suggested by the fact that both the Lamb Carcass Evaluation Workshop (Brannon *et al.*, 1964) and the Lamb Carcass Evaluation Committee of the AMSA (Field *et al.*, 1967) recommended utilization of these three prediction indices. The degree to which these committees drew upon the research results of Spurlock and Bradford (1965) is not known but is envisaged as being considerable.

Data presented in Table 1 substantiate previous

TABLE 1. THE ACCURACY[1] OF SELECTED PREDICTION EQUATIONS FOR ESTIMATING LAMB CARCASS CUTABILITY

Source of equation	Equation endpoint	Coefficient of determination[1] ($CD = r^2 \times 100$)
USDA (1969)	Yield grade	81.00
Field and Riley (1968)	Major semi-boneless cuts	76.56
Johnston et al. (1967)	Total boneless cuts	75.86
Field et al. (1963)	Total lean	71.57
Carpenter et al. (1969)	Retail primal cuts	67.90
Oliver (1967)	Total consumer cuts	67.08
Spurlock and Bradford (1965)	Retail primal cuts	63.84
Hoke (1961)	Retail primal cuts	46.51
Judge and Martin (1963)	Edible portion	41.22
Judge et al. (1966)	Edible portion	34.69

[1] Accuracy is defined such that the higher the CD value, the greater the proportion of variation in actual cutability (determined by processing the 577 individual carcasses) which was associated with the predicted cutability value (determined by fitting carcass measurements into a particular prediction equation).

recommendations for using the Field *et al.* (1963) formula, but suggest that more recent prediction equations may excel in predicting very closely trimmed primal cuts. Regression equations proposed by Johnson *et al.* (1967), USDA (1969), Field and Riley (1968), Carpenter *et al.* (1969) and Oliver (1967) were most closely related to the data of the present study. It is encouraging that the yield grade equation made available for commercial use (USDA, 1969) is highly related (CD = 81.00) to the actual cutout data.

Those indices which most closely estimated the data of the present study were equations designed to predict percent lean (Field *et al.* 1963), semi-boneless cuts (Field and Riley, 1968) and boneless cuts (Johnston *et al.*, 1967; USDA, 1969). These systems of evaluation more closely relate true muscle differences than do equations predicting bone-in and relatively fat cuts such as those of Hoke (1961), Judge and Martin (1963) and Judge *et al.* (1966). The Spurlock and Bradford (1965) equation was derived from bone-in cuts with 3.1 mm. of external fat, similar to cuts used in this investigation, and was highly correlated with the data of the present study. The equations of Oliver (1967) and Carpenter *et al.* (1969) were developed for predicting weight of consumer cuts, but both were highly correlated with the data from this investigation when converted to a percent of carcass weight basis.

Summary and Conclusions

Accurate evaluations of the endpoint of market lamb production depend largely upon assessments of carcass value. Extensive research conducted by the USDA, land-grant universities and the industry on lamb carcass cutability has resulted in the formulation of a number of prediction equations. It seemed pertinent not only to compare the USDA (1969) equation to the cutout data of the present study but also to determine its comparative accuracy in relation to the many equations previously reported. Measurements from each of 577 individual carcasses were fitted upon 10 prediction equations and the estimated yield of retail primal cuts compared with actual cutout data. The USDA (1969) equation was the most accurate (highest CD) prediction system studied for estimating lamb carcass cutability from simple carcass measurements. This equation combines simplicity, accuracy and ease of application and, as such, should provide a medium for improved market pricing structure. Moreover, the factors involved are related closely enough to traits in live lambs to allow producers to design breeding, feeding, selection and management systems to maximize the production of consumer-preferred lambs.

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PR-2742

Factors Affecting Lamb Carcass Shrinkage

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Various factors which contribute to carcass shrinkage during post-slaughter chilling and shipment to major retail distribution areas have not been clearly explained. Changes accompanying shrinkage, such as surface dehydration and deterioration of color, may significantly influence product shelf life and ultimately, consumer acceptability.

Degree of finish and carcass weight have been suggested as factors affecting shrinkage (Carpenter, 1966; Western Regional Project W-61, 1966).

Field and Riley (1968) reported average post-slaughter carcass shrinkages, based on 24-hour initial weights, of 1.09 percent at 72 hours, 2.17 percent at 1 week and 4.71 percent at 2 weeks. These figures indicate that percent shrinkage loss increases with time in the cooler, but at a declining rate. Fleming and Earle (1968) reported weight losses of 1.73 percent of the initial weight for 38-pound carcasses held at 81-percent relative humidity for the first 6 hours following slaughter. Field and Riley (1968) concluded that carcass shrinkage could be reduced by increasing carcass weight and the amount of fat covering on the carcass. To reduce carcass shrink by 0.10 pound over a 1-week period, 1 pound of external fat would need to be added to the carcass. However, additional fat decreases lean cut yields; therefore, producing heavier and leaner lambs would be the most practical means of decreasing carcass shrink (Field and Riley, 1968). Carpenter, King and Koenig (1968) suggested that degree of finish was of relatively minor importance in reducing shrinkage but that light-weight, thinly finished carcasses sustained greater shrinkage losses than did heavier, thicker finished carcasses.

Differences in carcass weight and finish have not been conclusive in explaining weight losses during cooler storage. This study was initiated to determine the effects of initial carcass weight, conformation equivalent (shape), final grade, fat cover completeness score and fat thickness on weight loss in lamb carcasses which results from shrinkage while in a storage cooler.

Experimental Procedure

Three-hundred forty lamb carcasses were selected from a single day's production in a commercial packing plant and weight losses recorded over a 72-hour period of cooler storage. The population of carcasses contained both ewes and wethers, ranged in weight from 38 to 81 pounds, and in grade from average Good to high Prime (USDA standards) and varied in subcutaneous fat thickness from 0.04 to 0.54 inches. The carcasses were processed by routine slaughter procedures, thoroughly washed and placed in refrigerated storage for 72 hours.

Three-hundred of the carcasses were individually suspended from hooks without shrouds or any protective covering. Forty additional carcasses were placed on individual hooks and covered with water-impermeable plastic bags from which all the surrounding air was evacuated manually and which were carefully tied at the top to prevent evaporative loss. Water lost in the form of drip accumulated in the bag and was weighed. After the bag was removed, each carcass was exposed to the prevailing airflow in the cooler for 12 hours to measure evaporative loss. Weights were recorded for the 300 carcasses to the nearest 0.05 pound immediately after washing and at 12-hour intervals thereafter. The cooler was equipped with a recording hygro-thermograph for temperature and relative humidity determinations. The cooler temperature varied from 36 to 38° F., and the relative humidity ranged from 88 to 92 percent during the period of storage.

Each carcass was assigned scores for conformation equivalent and final grade by a representative of the Meat Grading Branch, Consumer and Marketing Service (CMS) USDA and for completeness of subcutaneous fat covering by a committee of three Texas A&M University personnel. Fat probe measurements were taken over the 1. *dorsi* (rib eye muscle) using a swine backfat probe.

Results and Discussion

Amount of external finish and carcass weight have been used in attempts to account for lamb carcass shrinkage during holding periods in the storage cooler. In the present study, conformation score, final grade and fat cover completeness score were studied in addition to fat thickness and carcass weight measures to determine their individual and accumulative effects on percent weight loss during the 72-hour period post slaughter. Data presented in Table 1 divide the 72-hour weight loss into percentages by 12-hour intervals. The 300 carcasses, held without protective coverings, lost 1.87 percent of their initial carcass weight in the first 12-hour interval. Since the 40 carcasses in plastic bags accumulated 1.65 percent of their carcass weight as drip loss and a total of 1.76 percent as combined weight loss (drip plus 12-hour evaporative loss), it is believed that most of the initial decrease in carcass weight is that from water added in the washing procedure.

The weight lost during the ensuing 60-hour period probably results from moisture loss in the form of evaporation from the carcass components. Approximately 39 percent of the weight loss occurred during this period. Of particular interest is the fact that 92.73 percent of the weight loss occurred during the initial 36-hour interval. These data suggest that the first 36

TABLE 1. PERCENT OF 72-HOUR WEIGHT LOSS BY 12-HOUR INTERVALS

Interval, post slaughter	Average weight loss, 12-hour interval, percent	Percent of 72-hour weight loss
12 hours	1.87	61.23
24 hours	2.31	75.79
36 hours	2.83	92.73
48 hours	2.89	94.62
60 hours	2.96	97.12
72 hours	3.05	100.00

TABLE 2. SIMPLE CORRELATION COEFFICIENTS FOR CERTAIN CARCASS VARIABLES

Trait	df	Final grade[1]	Fat cover score[2]	Fat probe, milligram[3]	Carcass weight, kilogram	Weight loss (72 hours), percent[4]
Conformation score[1]	298	0.70	−.41	0.43	0.40	− .55
Final grade[1]	298		−.51	0.57	0.53	− .50
Fat cover score[2]	298			− .62	− .45	0.33
Fat probe, milligram[3]	298				0.52	− .53
Carcass weight, kilograms	298					− .43

[1] Scores assigned by personnel of Meat Grading Branch, USDA, CMS.
[2] Subjective scores based on visual standards: 1 is completely covered with subcutaneous fat while 7 is decidedly underfinished.
[3] Fat probe taken 1½ inches from the midline over the *l. dorsi* between the 12th and 13th ribs.
[4] Percent of initial washed carcass weight.

hours after slaughter is the most critical time for maintaining environmental conditions which are least conducive to shrinkage. Such measures would include the maintenance of low temperature conditions with minimal air circulation, a high relative humidity and a reduction in the number of times carcasses are shifted while on the rail during cooler storage (Breidenstein, 1969). Weight losses sustained under conditions involving periods of cooler storage longer than 24 hours are probably the result of actual tissue dehydration and thus may be much more closely related to differences among carcasses.

Simple correlation coefficients (Table 2) suggest that decreased surface area and/or increased amounts of subcutaneous fat covering are the major variables associated with decreased weight losses from lamb carcasses during storage in refrigerated coolers. The surface area of the body varies approximately in proportion to (weight) 0.67, but is more accurately predicted by the formula: Surface Area = Weight (0.425) x Height (0.725) x 0.007184 (Guyton, 1968). Increased carcass weight (Table 2) results in decreased weight loss (r = −.43) as a partial result of the exponential decrease in exposed surface area per unit of carcass weight. Furthermore, since genetic growth potential decreases in the order of bone, muscle and fat tissues, increases in weight beyond skeletal maturity (approximately 60 pounds carcass weight for most strains of sheep) are partially muscle, but largely fat. The latter response results in essentially fixed carcass lengths (height), more muscle tissue per unit of length and decided increases in the thickness of the subcutaneous fat cover —changes which effect lessened surface areas per unit of volume exposed for evaporative loss.

Conformation score is defined as the ratio of carcass width in relation to length (USDA, 1960) such that higher scores are assigned to carcasses with short, wide and blocky configurations which are often accompanied by increases in external fat cover. Correspondingly, increases in conformation scores are associated with smaller surface areas exposed and thereby with lesser proportions of weight loss during storage (r = −.55, Table 2). Since conformation score is a component of final grade (r = 0.70, Table 2) and increased fatness is a requisite for higher final grade ratings, final grade is similarly associated with decreases in shrinkage loss (r = −.50, Table 2).

Increases in the thickness of the subcutaneous fat layer (r = −.53) and in the distribution of such fat (r = 0.33) attest to the relationship of adipose deposition in reducing weight losses. Increased fatness may result in decreased weight loss by either of two functional relationships. First, fat may serve in an insulating capacity, thereby reducing the effective moisture-vapor transmission rate from the exterior of muscle to the surrounding air currents. Conversely and second, since adipose tissue contains less moisture than muscle (30 and 70 percent, respectively, for adipose versus muscle tissues) the reduction in shrinkage for fatter carcasses may result from the lower total moisture content inherent in more heavily finished carcasses.

It appears from these data that as carcass weight and fat thickness increase, there is a corresponding decrease in weight loss, which is in agreement with Field and Riley (1968). The low correlation (r = 0.33) between fat cover score and weight loss is difficult to explain since it would seem that with a more uniformly distributed fat covering there would be less carcass area susceptible to dehydration.

In Table 3, mean separation analysis for conformation and weight loss are illustrated. Those carcasses with a conformation score of average or high Good sustained significantly ($P<.05$) greater shrink losses

TABLE 3. SHRINKAGE OF LAMB CARCASSES DIFFERING IN CONFORMATION SCORE

Conformation score	n	Weight loss—72 hours, percent of initial weight
Average Prime	7	2.34
Low Prime	16	2.86 [d]
High Choice	49	2.97 [cd]
Average Choice	101	3.09 [bc]
Low Choice	72	3.12 [b]
High Good	50	3.40[a]
Average Good	5	3.59[a]

[abcd]Values having a common superscript are not significantly different ($P<.05$).

TABLE 4. EFFECT OF FINAL CARCASS GRADE UPON WEIGHT LOSS DURING COOLER STORAGE

Final grade	n	Weight loss—72 hours, percent of initial weight[1]
Average Prime	4	2.97
Low Prime	21	3.09
High Choice	29	3.09
Average Choice	115	3.13
Low Choice	104	3.15
High Good	25	3.06
Average Good	2	2.88

[1] Differences were not significant (P <.05).

than carcasses with Prime or Choice grade conformation. The low and average Choice carcasses shrank significantly (P<.05) more than carcasses with conformation scores from high Choice through average Prime. Carcasses with average Prime conformation lost significantly less weight than all other groups. Carcasses with conformation scores equal to or exceeding high Choice would lose less weight due to shrinkage while held in a storage cooler.

When maturity and quality scores are combined with that for conformation, final grade may be derived (Table 4). There were no significant differences (P<.05) in cooler shrinkage among carcasses varying in USDA grade. These data further suggest that the width-thickness relationship used to determine the conformation score significantly affects the surface area available for moisture loss. As conformation score increases, the surface area per unit of weight lessens, and there is a corresponding decrease in weight loss due to shrinkage.

From the data in Table 5, it appears that a uniform fat covering is relatively unimportant in controlling weight loss. Significant differences occurred only between the extremes of the scoring system, which may indicate that an intact fell membrane is sufficient covering to reduce carcass shrink. However, when fat thickness over the ribeye muscle is considered (Table 6), it appears that some minimum level of subcutaneous finish is necessary to reduce cooler shrink. Those carcasses with less than 0.10 inches of fat covering shrank significantly (P<.05) more than those with 0.11 inches

TABLE 5. EFFECT OF COMPLETENESS OF FAT COVERING UPON WEIGHT LOSS OF LAMB CARCASSES

Fat cover score	n	Weight loss—72 hours, percent of initial weight
1	16	3.19[ab]
2	36	3.11[abc]
3	57	3.16[a]
4	63	3.00[abc]
5	50	2.97[bc]
6	54	2.93[c]
7	24	3.02[abc]

[abc] Values having a common superscript are not significantly different (P <.05).

TABLE 6. EFFECT OF FATNESS UPON SHRINKAGE OF LAMB CARCASSES

Fat probe inches	n	Weight loss—72 hours, percent of initial weight
0.00-0.10	43	3.58
0.11-0.15	58	3.17[a]
0.16-0.20	74	3.08[ab]
0.21-0.25	38	3.02[abc]
0.26-0.30	44	3.04[abc]
0.31-0.35	14	2.84[bc]
0.36-0.40	17	2.92[bc]
0.41-over	12	2.76[c]

[abc] Values having a common superscript are not significantly different (P <.05).

and above; those with 0.11 to 0.15 inches of external fat shrank significantly more than those with 0.31 inches or more. With a 0.10 inch increase in fat thickness, there is a corresponding reduction in yield grade of approximately two-thirds of a grade. Economically, the monetary return associated with reducing shrinkage would not compensate for the carcass value decrease resulting from an increase in fat thickness.

The mean separation analysis for carcass weight and cooler shrinkage (Table 7) suggests nonsignificant differences (P<.05) between weight groups. This is in disagreement with Field and Riley (1968) who found that as carcass weight increased, there was a decrease in shrinkage.

Table 8 provides a comparison of several multiple regression equations and the accuracy (coefficient of determination) with which these variables can be used to predict carcass shrinkage. The independent variables used in equation 1 were conformation score, final grade, fat cover score, fat probe and carcass weight. This equation would be 42.39 percent accurate in accounting for the variation in the 72-hour loss in carcass weight. Equations 2 through 6 illustrate the reduction in accuracy when a single independent variable is deleted. The greatest reductions in predictive accuracy occur when either conformation score or fat probe are deleted from the equation. Equations 7 and 8 illustrate the reduction in accuracy when other independent variables are deleted. It is evident that little accuracy is lost so long as conformation score and fat probe are used in the equation. In equation 9 versus 10, conformation score and fat probe are 5 percent

TABLE 7. SHRINKAGE OF CARCASSES IN VARIOUS WEIGHT GROUPS

Carcass weight groups, pounds	n	Weight loss—72 hours, percent of initial weight[1]
50 and less	32	3.14
50.0-54.9	87	3.08
55.0-59.9	74	2.99
60.0-64.9	55	3.10
65 and over	52	2.95

[1] Differences were not significant (P <.05).

TABLE 8. ESTIMATES OF LAMB CARCASS SHRINKAGE

Equation	1	2	3	4	5	6	7	8	9	10
Independent variable					Weight loss, percent					
Conformation score	X[1]	X		X	X	X	X	X	X	X
Final grade	X	X	X		X	X	X			
Fat cover score	X	X	X	X		X		X		
Fat probe	X	X	X	X	X		X	X	X	
Carcass weight	X		X	X	X	X				X
R^2 x 100	42.39	41.48	35.77	42.32	41.72	35.98	40.96	41.22	40.80	35.04

[1] The "X" indicates use of that independent variable in the regression equation.

more accurate than conformation score and carcass weight. If either the fat probe or the conformation score is removed from the equation, the greatest reduction in accuracy occurs. Field and Riley (1968) could account for only 8 percent of the variation in shrink loss using an equation combining carcass weight and fat thickness.

Summary

Three-hundred forty lamb carcasses ranging in weight from 38 to 82 pounds, in grade from average Good to high Prime and in subcutaneous fat thickness from 0.04 to 0.54 inches were used in this study. Carcass weights were recorded to the nearest 0.05 pounds immediately after washing and at 12-hour intervals thereafter for a total of 72 hours.

From these data it appears that the first 36 hours is the most critical time period in the shrinkage of lamb carcasses. Ninety-two percent of the weight loss occurred during this time interval—loss partially a result of evaporation and drip loss of wash water and the remainder a result of loss of moisture from the carcass components.

The simple correlations illustrated the part-whole relationship between conformation score, carcass weight, degree of finish and final grade. From these analyses it appears that as carcass weight and fat thickness increase, weight loss decreases. Fat cover score was relatively unimportant in its relationship to weight loss. The correlation between conformation score and weight loss supports the theory that as conformation increases, there is a corresponding decrease in relative surface area and, consequently, less area is available for moisture loss.

Mean separation analyses suggest that carcasses scoring high Choice or higher in conformation score shrink significantly less than the carcasses with lower scores. Carcasses with Good grade conformation scores shrank significantly more than those scoring either Prime or Choice. No significant differences were found among carcasses of different final grades ranging from average Good to average Prime. For fat cover scores, significant differences were found only for the extremes of the scoring system, which suggest that completeness of fat covering is relatively unimportant in relation to weight loss. The monetary return which results from reducing shrinkage by additional fatness would not compensate for the loss in value involved in reducing cutability.

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Specific Gravity for Measuring Lamb Carcass Composition

N. J. ADAMS AND Z. L. CARPENTER

Currently the most reliable method for determining lamb carcass value is to cut the carcass into trimmed retail cuts. However, final carcass value can be rather accurately estimated by use of equations derived from previous carcass data. Such estimates are less expensive and are more rapidly obtained without actual cutting of the carcass. There is a need for an accurate yet simple and inexpensive method of determining lamb carcass composition.

It has been established that the body is comprised of a fat-free body mass of constant gross composition and a variable quantity of fat. Hence, fat with a low density, as compared with that of muscle and bone, can be regarded as being primarily responsible for deviations in gross composition. Since a given volume of fat is less dense, or weighs less than the same volume of muscle, composition or the percent of each of the three major components (bone, lean, fat) can be rather accurately estimated by determining the density of the total body mass. The technique most often used to estimate composition is termed "specific gravity". The procedure for determining specific gravity of a carcass is simple and does not require expensive equipment. It involves weighing an intact carcass or a carcass section in air and then obtaining the weight of the same portion submerged in water. The specific gravity values obtained by this method can then be used to estimate carcass composition.

It has been reported by numerous workers that specific gravity is a useful tool to estimate body composition in meat animals. The results of studies using specific gravity have been consistent in describing an inverse relationship between carcass fat and carcass specific gravity. The extent of this relationship, as measured by the correlation coefficient, has been variable.

A study was undertaken to investigate the use of specific gravity for estimating lamb carcass composition.

Experimental Procedure

Carcasses from forty-six ewe and wether lambs, the progeny of Rambouillet ewes and either Hampshire or Suffolk rams, were used in this study. Carcasses ranged in weight from 39 to 68 pounds with an average 52.5. Following slaughter at the Texas A&M University Meat Laboratory, the carcasses were chilled at 34° F. for 48 hours before specific gravity measurements were taken. Specific gravity determinations were obtained for the whole carcass, foresaddle, hindsaddle and hindsaddle with kidney and kidney fat removed.

After certain carcass measurements were taken, the carcasses were processed into trimmed retail cuts.

Composition was estimated by utilization of the specific gravity values derived from each carcass. These values were then utilized in estimating equations previously reported by Timon and Bichard (1965) and Meyer (1962).

Results and Discussions

The mean specific gravity values for the whole carcass, foresaddle, hindsaddle and hindsaddle with kidney and kidney fat removed were 1.0467, 1.0502, 1.0428 and 1.0480, respectively. These values indicate that the leanest carcass section was the foresaddle followed by the hindsaddle with kidney and kidney fat removed, the intact carcass and the hindsaddle.

Table 1 provides a comparison between each carcass section, the estimated composition values and the relationship to three carcass traits. Specific gravity of the hindsaddle was most highly related to measures of carcass lean and fat.

Correlation coefficients between percent retail cuts and specific gravity of the carcass and each section were positive and relatively high in magnitude.

Percent fat trim and fat thickness measures were negatively correlated with specific gravity values for the carcass and each section. The correlation coefficients were higher for fat trim and specific gravity than for fat thickness and specific gravity.

Since specific gravity of the hindsaddle was the most reliable predictor of carcass composition, this measure was utilized to develop prediction equations. The simple regression equation for estimating percent

TABLE 1. SIMPLE CORRELATION COEFFICIENTS FOR CERTAIN CARCASS COMPOSITION MEASURES

	Carcass measurements		
	Retail cuts, percent	Fat trim[1], percent	Fat thickness[2], percent
Whole carcass			
Specific gravity	0.59	− .55	− .46
Fat, percent[3]	− .59	0.55	0.46
Fat, percent[4]	− .59	0.55	0.46
Fat, percent[5]	− .66	0.61	0.60
Muscle, percent[3]	0.59	− .55	− .46
Protein, percent[6]	0.66	− .60	− .59
Fat-free carcass, percent[6]	0.66	− .61	− .60
Foresaddle			
Specific gravity	0.64	− .68	− .47
Fat, percent[3]	− .64	0.69	0.47
Fat, percent[4]	− .69	0.69	0.47
Fat, percent[5]	− .64	0.72	0.56
Muscle, percent[3]	0.69	− .69	− .47
Protein, percent[6]	0.69	− .72	− .55
Fat-free carcass, percent[6]	0.64	− .72	− .56
Hindsaddle			
Specific gravity	0.78	− .71	− .68
Fat, percent[3]	− .78	0.72	0.68
Fat, percent[4]	− .78	0.71	0.68
Fat, percent[5]	− .79	0.72	0.73
Muscle, percent[3]	0.78	− .71	− .68
Protein, percent[6]	0.80	− .72	− .73
Fat-free carcass, percent[6]	0.79	− .72	− .73
Hindsaddle[7]			
Specific gravity	0.74	− .67	− .65
Fat, percent[3]	− .74	0.67	0.65
Fat, percent[4]	− .71	0.66	0.64
Fat, percent[5]	− .76	0.68	0.71
Muscle, percent[3]	0.74	− .67	− .65
Protein, percent[6]	0.73	− .65	− .69
Fat-free carcass, percent[6]	0.76	− .68	− .71

$P < .05 = .291$ and $P < .01 = .376$ for 44 degrees of freedom.

[1] Does not include kidney and kidney fat.
[2] Average of eight measures.
[3] Derived from equation of Timon and Bichard (1965).
[4] Derived from single regression equation of Meyer (1962).
[5] Derived from multiple regression equation of Meyer (1962).
[6] Taken from the work of Meyer (1962).
[7] Kidney and kidney fat removed.

fat trim from specific gravity of the hindsaddle was:

Carcass fat trim (percent) = 240.72 − 214.74 (specific gravity of hindsaddle).

In this equation the coefficient of determination was 0.51, and the addition of chilled carcass weight to the regression did not significantly improve the predictive value.

The simple regression equation for estimating percent retail cuts from specific gravity of the hindsaddle was:

Retail cut (percent) = − 175.98 + 225.99

(specific gravity of hindsaddle).

The coefficient of determination in this equation was 0.61, and the addition of carcass weight to the predictive equation increased accuracy by only a small degree ($R^2 = 0.635$ compared to 0.608).

On the basis of the data collected in this study from the 46 lamb carcasses and the use of the existing predictive equations, specific gravity appears to have merit in estimating carcass composition. The specific gravity of the hindsaddle tends to be a more reliable predictor than the whole carcass or other sections studied.

Estimates of composition as derived from equations using specific gravity values of the hindsaddle appear high enough to use with groups of lambs to detect differences due to treatment. However, additional precision must be attained before wide use of this technique can be recommended.

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PR-2744

Indicator Cuts for Estimation of Lamb Carcass Composition

N. J. Adams and Z. L. Carpenter

Results of research in breeding, nutrition, or other production studies are evaluated from differences in performance of the animals in the different treatment groups. In many instances, the effects of certain treatments upon carcass composition are of interest. Consequently, one of the major purposes of carcass evaluation is to more accurately assess changes or differences in composition.

Chemical analysis of the entire animal body will yield the most satisfactory and accurate data on composition. A complete dissection or separation of the carcass into the three major components (muscle, fat and bone) is another valid measure of carcass composition. Both of these methods for determination of composition are expensive and laborious. Research workers have been interested in simplified methods for estimating the major components of composition with adequate accuracy.

Researchers have identified certain portions of the carcass which contain approximately the same proportion of lean, fat and bone as does the entire carcass. Early work by Hankins and Howe (1946) found that the 9, 10, 11 rib section of the beef carcass contained approximately the same proportion of lean, fat and bone as the entire beef carcass. That work established this cut as an "indicator cut" for beef carcasses, and it has been used extensively to estimate total carcass composition in beef studies. Additional work by Hankins (1947), as well as more recent work by other workers, has shown the composition of the rib section in lamb carcasses to be a good indicator of total carcass composition.

With more interest on the composition of the carcass and more research terminating with the evaluation of carcass composition, these types of evaluation procedures appear essential. Valuable time and expense can be saved in processing only a portion of a carcass if the composition data derived are closely related to those of the entire carcass.

This study was conducted to examine the value of using certain cuts and the specific gravity of these cuts as indicators of carcass composition.

Experimental Procedure

The wholesale untrimmed cuts from the left side of 46 lamb carcasses described in PR-2743 were used in this study. Specific gravity determinations were made on the untrimmed leg, loin, shoulder and rack.

Following specific gravity determinations on the wholesale rack, this cut was physically separated into lean, fat and bone. These data are reported as separable lean and separable fat of the rack. The fat and lean portions were combined, ground, mixed and sampled by the "serial halving technique". Proximate analysis for fat (ether extract) and moisture content (oven drying) were completed on aliquots of the mixed ground samples of the rack according to the methods of Association of Official Agricultural Chemists (AOAC) (1965).

Composition was estimated by utilization of the specific gravity values derived on each cut and by use of the previously reported equations of Meyer (1962) and Timon and Bichard (1965).

Results and Discussion

Specific gravity values of the leg were highest (1.0771), followed by the shoulder (1.0493), rack (1.0413) and loin (1.0305) which indicates that the leg is the leanest cut followed by the shoulder, rack and loin.

TABLE 1. SIMPLE CORRELATION COEFFICIENTS AMONG CERTAIN MEASURES OF CARCASS COMPOSITION

	Carcass measurements		
Specific gravity values	Retail cuts, percent	Fat trim[1], percent	Fat thickness[2], percent
Wholesale rack	0.64	−.72	−.58
Wholesale shoulder	0.16	−.63	−.17
Wholesale loin	0.66	−.69	−.59
Wholesale leg	0.57	−.62	−.50

$P < .05 = .291$ and $P < .01 = .376$ for 44 degrees of freedom.

[1] Does not include kidney and kidney fat.

[2] Average of eight measures.

Table 1 shows the correlation coefficients between each cut and three measures of carcass desirability. These data suggest that the specific gravity and composition estimates from the 7-rib rack and the loin cuts are sufficiently related to whole carcass measures to be of considerable predictive value.

Correlation coefficients between various rack and carcass measures are presented in Table 2. Chemically determined fat of the rack (40.16 percent) was more closely related to measures of carcass value than was protein of the rack (14.78 percent) determined by chemical analysis. Both separable fat (37.78 percent) and lean (45.52 percent) of the rack were good indicators of measures of value in the carcass. Conformation score, normally thought of as an indicator of carcass value, was positively related to measures of fat and negatively related to measures of lean.

The results of this study indicated that the rack, loin and leg would be of value as sample cuts to predict composition in the carcass. These cuts could be used for specific gravity determinations, but the 7-rib rack would have an advantage if the separation method is used. The untrimmed 7-rib rack in this study represents approximately 8 percent of the total carcass weight and required on the average 1 hour to separate into components.

TABLE 2. SIMPLE CORRELATION COEFFICIENTS BETWEEN VARIOUS RACK AND CARCASS MEASURES

	Rack			
	Protein, chemical	Fat, chemical	Lean, separable	Fat, separable
Specific gravity (rack)	0.57	− .78	0.78	− .82
Specific gravity (hindsaddle)	0.46	− .76	0.49	− .75
Carcass weight	− .48	0.63	− .73	0.75
Conformation score	− .20	0.21	− .26	0.35
Loin eye area	− .04	0.16	− .26	0.36
Retail cuts, percent	0.50	− .76	0.78	− .75
Fat trim, percent	− .56	0.83	− .71	0.79
Fat thickness, average of eight	− .58	0.79	− .73	0.83

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PR-2745

Relationship of USDA Carcass Grades To Palatability of Lamb Cuts

H. R. Cross, G. C. Smith and Z. L. Carpenter

Lamb carcass grades are designed to classify carcasses into groups of differing commercial market value. Carcass-grading standards specify requirements for "quality of lean flesh" (texture, firmness and marbling in relation to apparent maturity) which can be evaluated indirectly by using scores for feathering, flank streaking, and firmness of the fat and lean (USDA, 1969). Consumers evaluate quality on the basis of the palatability properties of cooked meat. Therefore, the ultimate goal of quality evaluation in ovine carcasses is the accurate estimation of palatability and acceptance by the consumer.

Precise federal grading should benefit the industry because the consistent availability of lamb of a desired quality level is likely to increase consumer acceptance and demand. Reports of Stouffer *et al.* (1958) and Paul, Torten and Spurlock (1964a, b, c) support the use of USDA carcass grades for segregating lamb into palatability groups. Forrest (1962), Weller, Galgan and Jacobson (1962) and Carpenter and King (1965a, b) reported low relationships between lamb carcass quality grades and palatability attributes.

The present investigation was designed to compare the palatability characteristics of ovine meats selected from different USDA grades.

Experimental Procedure

A total of 480 primal cuts from lamb and yearling mutton carcasses was selected to achieve representative samples from USDA grades Prime, Choice, Good and Utility.

Carcasses which would produce such cuts were selected from a commercial plant by an official representative of the Meat Grading Branch, C&MS,

USDA, according to the official standards (USDA, 1969). Four 18-member taste panels, given preliminary training and instruction, evaluated the palatability characteristics of both leg roasts, rib chops and loin chops from each carcass. All cuts were cooked to an internal temperature of 75° C. in a preheated gas oven (177° C.). A nine-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely) was used to rate each sample according to its desirability of flavor, juiciness, tenderness and overall satisfaction characteristics. Scores from both leg roasts and the rib and loin chops from each carcass were averaged and analyzed as palatability scores for primal cuts.

Results and Discussion

Successful grading systems ultimately depend upon the characteristics of the product, the variability within and among meat samples and accurate assessments of consumer desires and preferences. Most consumers prefer lamb that is flavorful and tender and which combines palatability characteristics to result in an eating experience which is satisfactory to all the senses (touch, taste, odor, sight and so forth). Results presented in Table 1 relate the component scores of USDA lamb carcass grading standards to the palatability traits of lamb cuts. Scores for feathering, flank streaking, flank firmness and maturity are used in commercial practice to assign quality grades to lamb carcasses. Of those traits, only that for flank streaking (Table 1) is significantly related to flavor, tenderness and overall satisfaction ratings (r values-0.29, 0.33 and 0.40, respectively). Corresponding differences in USDA quality grade were associated with less than 8 percent of the differences in overall satisfaction ratings for lamb cuts. To achieve a final grade, the USDA combines scores for conformation (shape) with those for quality grade. Although higher USDA quality grades were associated with increased levels of palatability, the addition of carcass conformation to the quality grade did not contribute significantly to the ability of final grades to segment carcasses according to their overall palatability. It might also be noted from Table 1 that scores for flank streaking were more closely related to

TABLE 1. SIMPLE CORRELATION COEFFICIENTS BETWEEN TASTE PANEL RATINGS AND USDA QUALITY INDICATOR SCORES[1]

Quality indicator scores	Flavor ratings	Tenderness rating	Overall satisfaction rating
Feathering	0.05	0.25**	0.21*
Flank streaking	0.29**	0.33**	0.40**
Flank firmness	0.04	0.22**	0.17
Maturity	— .01	0.15	0.10
USDA quality grade	0.07	0.34**	0.27**
USDA final grade	0.07	0.32**	0.26**

[1] Average taste panel ratings from primal cuts.
*P <.05.
**P <.01.

TABLE 2. MEAN VALUES FOR FLAVOR, TENDERNESS AND OVERALL SATISFACTION RATINGS AMONG USDA QUALITY GRADES

Basis of comparisons	USDA quality grade[1]	n[2]	Flavor rating[3]	Tenderness rating[3]	Overall satisfaction rating[3]
Between grades	Prime	72	5.87	6.38	6.03
	Choice	240	5.87	6.12	5.81
	Good	112	5.78	5.98	5.68
	Utility	56	5.78	5.60	5.58
Within the Choice grade	High Choice	52	5.99	6.24	5.94
	Average Choice	64	5.74	6.14	5.78
	Low Choice	124	5.88	6.06	5.78

[1] USDA quality grade, disregarding conformation score.
[2] Combined ratings for two sets of leg roasts, loin chops and rib chops from each carcass.
[3] Mean hedonic (pleasure) ratings based on a 9-point numbering system in which 6 = like slightly and 5 = neither like nor dislike.

palatability ratings than were those for USDA final grade.

Mean values for palatability ratings (Table 2) suggest little difference in flavor scores among cuts from different USDA quality grades. Carcasses graded Prime were more tender and more satisfactory in overall palatability than were those of lower USDA grades. As grade decreased from Prime through Utility, taste panel ratings (Table 2) decreased; but the actual differences between adjacent grades were often small. Although considerable recognition is sometimes given to the placement of a carcass within the Choice grade (high versus average or low), little research has been reported to substantiate such decisions. Data in Table 2 indicate that the segment denoted high Choice is associated with superior flavor, tenderness and overall satisfaction ratings. There is little difference in palatability ratings between cuts from the average and low segments of the Choice grade.

To be effective, grading standards for lamb carcasses should: (a) separate the product into categories possessing similar characteristics (Brandow, 1961); (b) reflect distinctions that the trade accepts as having meaning in terms of consumer preferences (USDA, 1962); (c) reflect differences in value between grades such that consumers are willing to pay different prices for different "qualities" (Fienup *et al.,* 1963); (d) achieve a balance between precision and accuracy with cost and ease of application (Breimyer and Dause, 1958); and (e) segment carcasses into groups with similar palatability attributes (Smith *et al.,* 1970).

Percentages of desirable versus undesirable panel ratings for primal cuts within USDA quality and final grades are presented in Table 3. There were no undesirable ratings for flavor, tenderness or overall satisfaction in either the prime quality or final grades. USDA quality standards did not accurately segment carcasses of Prime and Choice into grades according

TABLE 3. PERCENTAGES OF DESIRABLE OR UNDESIRABLE PANEL RATINGS[1] FOR PRIMAL CUTS WITHIN USDA QUALITY AND FINAL GRADES

		Flavor ratings[1]		Tenderness ratings[1]		Satisfaction ratings[1]	
		Desirable[2]	Undesirable[3]	Desirable[2]	Undesirable[3]	Desirable[2]	Undesirable[1]
USDA quality grades	Prime	46.15	0.00	61.54	0.00	30.77	0.00
	Choice	45.00	5.00	61.67	6.67	38.33	4.00
	Good	35.72	3.57	46.43	3.57	17.86	7.14
	Utility	26.32	5.26	26.32	15.79	15.78	10.52
USDA final grades	Prime	42.86	0.00	71.43	0.00	42.86	0.00
	Choice	43.28	4.48	58.21	5.97	35.82	5.97
	Good	31.58	2.63	44.74	5.26	18.42	7.89
	Utility	50.00	12.50	25.00	25.00	12.50	12.50

[1] Values in each column represent the percentages of total cuts tested in each category which were desirable or undesirable in palatability.
[2] Desirable ratings are those which were 6 or higher in hedonic score (like slightly or higher).
[3] Undesirable ratings are those which were 4 or lower in hedonic score (dislike slightly or lower).

to percentages of desirable ratings for flavor, tenderness or overall satisfaction. However, cuts from grades below Choice were inferior in palatability to cuts from Prime and Choice. Combining the conformation score with quality grade to achieve a final grade increased segmentation accuracy between grades for tenderness and overall satisfaction ratings, but drastically reduced accuracy in predicting proportions of desirable flavor scores (Table 3). As final grade decreased, the percentages of desirable ratings for tenderness and overall satisfaction decreased.

The results of the present study suggest that USDA grading standards for lamb carcasses are not as highly related to palatability as is desirable for accurate segmentation and marketing functions.

Summary and Conclusions

Primal cuts from carcasses grading Prime, Choice, Good and Utility were used in palatability studies designed to measure the accuracy of USDA standards. USDA grades for lamb carcasses do not accurately segment carcasses into palatability groups. Simple correlation coefficients indicate less than 8 percent accuracy for quality or final grades in estimating overall satisfaction ratings. Mean values for palatability ratings decreased as quality grade decreased, but the actual differences between grades are rather small. The inclusion of conformation scores for assigning final grades results in lowered segmentation accuracy for flavor desirability but does materially improve the consistency for tenderness and overall satisfaction scores between carcasses graded Prime as opposed to Choice.

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PR-2746

Palatability Characteristics Of Yearling Mutton Carcasses

G. C. Smith, Z. L. Carpenter and G. T. King

The characteristic flavor of some lamb, yearling mutton and mutton has been cited as one reason for low consumption of meat from ovine animals (Batcher, Brant and Kunze, 1969). Latest *per capita* consumption figures for red meats in the United States indicate that of the total 170 pounds consumed, 2.4 percent was lamb and 0.2 percent was mutton (USDA, 1967).

People apparently differ in their concept of what constitutes "mutton" flavor, but recent studies by Smith *et al.* (1970a,b) suggest that increased flavor intensity or concentration of flavor precursors is the primary problem. Furthermore, some investigators have reported decreases in ovine tenderness with increased chronological age (Batcher *et al.,* 1962; Pearson, 1966), while other research indicates the opposite effect (Paul *et al.,* 1964) or no association (Weller, Galgan and Jacobson, 1962; Jacobson *et al.,* 1962).

The purpose of this study was to compare the palatability characteristics of cuts from lamb with those from yearling mutton carcasses.

Experimental Procedure

Forty carcasses were selected from each of the three maturity classes designated in the official grading standards (USDA, 1969) which are "A"—young lamb carcasses, "B"—mature lamb carcasses and "Y"—yearling carcasses.

Four independent taste panels, composed of 18, 18, 18 and 3 members, evaluated the palatability attributes of leg roasts (I), leg roasts (II), rib chops and loin chops, respectively, from each carcass (Smith *et al.,* 1969a,b). Flavor, juiciness, tenderness and overall satisfaction scores from both comparisons of leg roasts, the loin chops and the rib chops were combined, and the average value for each palatability attribute was designated as the primal cuts score.

Results and Discussion

Batcher *et al.* (1962) reported that lambs 11 to 14 months of age produced cuts with greater amounts of intramuscular fat, higher cooking loss percentages and lower tenderness ratings than animals 4 to 5 months of age. Paul *et al.* (1964) concluded that retail cuts from lambs that were 11 to 12 months of age generally received higher scores for flavor, juiciness, texture and tenderness than cuts from 5½-month-old lambs. In the present study, flavor ratings did not differ among cuts from young lambs, mature lambs and yearling mutton (Table 1). Young lamb carcasses produced cuts which were ($P < .05$) more juicy and tender than did carcasses from either of the other maturity classes. These latter results substantiate similar reports by Batcher *et al.* (1962) and Paul *et al.* (1964), but the findings regarding flavor are in disagreement with Weller, Galgan and Jacobson (1964). Oversall satisfaction ratings (Table 1) indicate that young lamb carcasses are superior to those of the yearling mutton class.

Percentages of desirable or undesirable panel ratings for primal cuts within maturity classes are presented in Table 2. Comparisons of this type offer information regarding the consistency with which specific groups of carcasses produce palatable cuts upon cooking. Values for percent desirability do not completely substantiate those for mean hedonic ratings with respect to flavor (Table 2). In the latter case, yearling mutton carcasses are less likely to produce flavorful meat cuts than either of the A or B maturity groups. Percentages of desirable ratings for juiciness and tenderness were higher for cuts from young lamb carcasses, but yearling mutton carcasses were superior to mature lambs in both categories. USDA (1969) grading standards for ovine carcasses specify that the presence of spool joints on the metacarpals is positive identification of yearling maturity status. Carpenter *et al.* (1969) reported a study in which 19, 34 and 53 percents, respectively, of the ewe lambs 10, 12 and 14 months of age possessed spool joints. The data of Table 2 suggest that a considerable number of the carcasses presently identified as yearlings are, in fact, very desirable in both juiciness and tenderness. It is apparent that the presence or absence of spool joints on a carcass is not absolutely indicative of its palatability characteristics.

Percentages of undesirable ratings for juiciness, tenderness and overall satisfaction (Table 2) are higher for yearling mutton than for either A or B maturity car-

TABLE 1. COMPARISON OF MEAN VALUES FOR PALATABILITY RATINGS WITHIN MATURITY GROUPS

Trait	Maturity group		
	A	B	Yearlings
Flavor rating[1]	5.82^{a}	5.88^{a}	5.78^{a}
Juiciness rating[1]	5.95^{a}	5.65^{b}	5.76^{b}
Tenderness rating[1]	6.26^{a}	5.86^{b}	5.96^{b}
Satisfaction rating[1]	5.89^{a}	5.73^{ab}	5.70^{b}

[a, b] Values bearing the same superscript letter are not significantly different at the .05 probability level.
[1] Means based on a 9-point hedonic scale (9 = like extremely; 1 = dislike extremely).

TABLE 2. PERCENTAGES OF DESIRABLE OR UNDESIRABLE PANEL RATINGS FOR PRIMAL CUTS WITHIN MATURITY CLASSES

Trait	Maturity group	Flavor rating[1]	Juiciness rating[1]	Tenderness rating[1]	Overall satisfaction rating[1]
Desirable[2]	A	42.50	42.50	67.50	37.50
	B	42.50	20.00	32.50	25.00
	Y[4]	35.00	27.50	57.50	25.00
Undesirable[3]	A	5.00	0.00	0.00	5.00
	B	2.50	7.50	7.50	5.00
	Y[4]	5.00	10.00	12.50	10.00

[1] Values in each column represent the percentage of the total primal cuts which were considered desirable or undesirable for that palatability trait.
[2] Mean palatability ratings of 6 or higher (like slightly or higher).
[3] Mean palatability ratings of 4 or lower (dislike slightly or lower).
[4] Y = yearling mutton carcasses.

casses. These results support the data of Table 1 and the hypothesis stated previously regarding the presence of spool joints. Some carcasses exhibiting spool joints are undoubtedly from animals of advanced maturity and correspondingly are more likely to produce cuts which are less juicy and tender than those from lambs.

Summary and Conclusions

Forty carcasses were selected from each of three maturity classes, processed and the leg roasts, loin chops and rib chops evaluated by taste panels. Young lamb carcasses excel in producing cuts which are flavorful, juicy, tender and satisfactory in overall palatability. In general, groups of yearling mutton carcasses produce cuts which are highly heterogeneous in palatability traits. Although average scores for the palatability traits are lower ($P<.05$) for cuts from yearling carcasses, mean values do not accurately relate the variability inherent within that maturity class. Classifications into maturity groups based on the presence or absence of spool joints result in the grouping together as yearlings of carcasses which possess tremendous variations in age at slaughter and, correspondingly, in observed palatability characteristics.

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PR-2747

Relationship of Firmness And Color Characteristics Of Subcutaneous Fat to Flavor And Aroma of Cooked Lamb

G. C. Smith and Z. L. Carpenter

In the American Sheep Producers Council (1964) survey, undesirable flavor (taste, odor or smell) was cited by 56 percent of those consumers who never served lamb as the primary reason for not purchasing ovine meat cuts. Wide differences exist among people in their ability to distinguish "lamb" versus "mutton" flavors (Joubert, 1956; Batcher, Brant and Kunze, 1969). Differences in flavor preference between "recent" versus "regular" consumers (Smith *et al.*, 1970a, b) suggest the problem may be that of flavor intensity rather than of species *per se*.

Flavor components in lamb are believed either to reside in or to be carried by fat tissues (Hornstein, 1967). Flavor is usually a composite of taste and aroma (Beidler, 1957), but in the flavor of lamb the aromatic factors are so intense that they far outweigh the major taste characteristics.

The present study was designed to relate visible characteristics of the subcutaneous fat cover in lamb carcasses to the flavor and aroma of cooked lamb.

Experimental Procedure

Flavor and aroma ratings from 600 individual samples of lamb and yearling mutton were used in studies designed to characterize the relationships between fat tissues and flavor components. Five semi-trained taste panels evaluated the flavor characteristics of cooked ovine meat cuts. Three aroma-analyses panels evaluated ground samples of subcutaneous fat, intermuscular (seam) fat, muscle, muscle plus subcutaneous and seam fat, and fell membrane from these same cuts. A hedonic rating scale ranging from 9 (like extremely) to 1 (dislike extremely) was used to rate samples according to flavor or aroma desirability. Samples of subcutaneous fat (external fat deposited between the skin and body) were scored by a two-member panel according to their firmness (hard, medium, soft or very soft) and color (white, cream, tan, light brown) characteristics.

Results and Discussion

Increased fatness has been reported to increase flavor desirability and/or intensity (Anonymous, 1931; Weber and Loeffel, 1932; Barbella, Hankins and Alexander, 1936; Cline and Eckblad, 1937). Other investigations report little association between fatness and flavor of lamb (Batcher *et al.*, 1962; Smith, Galgan and Weller, 1964; Paul, Torten and Spurlock, 1964; Riley and

TABLE 1. SIMPLE CORRELATION COEFFICIENTS BETWEEN FLAVOR RATINGS, PERCENT FAT AND AROMA SCORES

Trait	Leg roast flavor rating	Loin chop flavor rating	Rib chop flavor rating	Ground lamb flavor rating	Primal cuts flavor rating
Percent fat (marbling)	0.10	− .07	− .16	− .14	− .12
Subcutaneous fat aroma score	0.11	0.18*	0.16	0.11	0.20*
Seam fat aroma score	0.18*	0.24**	0.33**	0.18*	0.29**
Muscle aroma score	0.13	0.10	− .05	− .12	0.10
Muscle plus fat aroma score	− .06	0.08	0.16	0.15	0.08
Fell membrane aroma score	0.08	− .15	0.13	− .04	− .03

** P <.01
* P <.05

Field, 1967; Batcher, Brant and Kunze, 1969; Smith and Carpenter, 1970).

Results of the present study suggest that amount of marbling (percent fat) in the sample is not significantly related to flavor ratings for any of the cuts studied (Table 1). The aroma characteristics of seam fat were more closely related to panel flavor scores than those of subcutaneous fat deposits. Flavor scores for those samples (rib chops) containing the highest proportion of seam fat were most closely related to aroma scores for intermuscular fat ($r = 0.33$, Table 1). Hofstrand and Jacobson (1960) previously suggested a relationship between seam fat deposits and the aroma of lamb and mutton broths.

A number of comparisons (data not included in tabular form) have indicated that the addition of subcutaneous fat to samples of muscle improved aroma scores compared to those of lean alone. If the character of the fat deposited subcutaneously was indicative of its flavor or aroma enhancing properties, subjective evaluations of firmness and color might be useful for grading lamb carcasses. The data of Table 2 suggest that hard, white subcutaneous fat deposits are associated with high aroma and flavor ratings for lamb cuts. Conversely, soft and/or brownish-colored fats are associated with lesser proportions of desirable flavor and aroma scores. Very low flavor and aroma scores were not closely related to either firmness or color (Table 2).

Present standards for grading lamb carcasses include scores for firmness of fat and lean, but when such scores were related to the data of the present study they were not related to either flavor or aroma (data not presented in tabular form). Firmness scores for carcasses are confounded in this relation because amount of finish present in the areas evaluated influences the score.

The incidence of lamb carcasses exhibiting very soft, brownish-colored fat is relatively high, and numerous industry representatives have expressed concern regarding the shrinkage, shelf-life and handling qualities of such carcasses. In light of the palatability relationships enumerated in the present study, the character of external fat produced by lambs should be carefully controlled. Further research regarding the effects of breed, genetic strain, ration and management practices may be necessary to assist in alleviating or controlling this problem.

Summary and Conclusions

Flavor and aroma ratings from 600 individual cuts from lamb and yearling mutton carcasses were used to characterize the relationships between fat tissues and palatability characteristics. Specific characteristics (aroma, color and firmness) of the external fat covering appear to be more closely related to the flavor ratings than does marbling. Carcasses exhibiting hard, white subcutaneous fats produced higher proportions of retail cuts with very high flavor and aroma scores than did carcasses with soft, brown-colored external fat.

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TABLE 2. RELATIONSHIPS OF SUBCUTANEOUS FAT CHARACTERISTICS TO FLAVOR AND AROMA SCORES

Trait		Very high aroma score,[1] percent	Very low aroma score,[2] percent	Very high flavor score,[3] percent	Very low flavor score,[4] percent
Character of subcutaneous fat[5]					
Firmness:	Hard	60.0	25.0	60.0	30.0
	Medium	30.0	15.0	30.0	20.0
	Soft	10.0	30.0	5.0	25.0
	Very soft	0.0	30.0	5.0	25.0
Color:	White	65.0	30.0	55.0	30.0
	Cream	25.0	15.0	35.0	25.0
	Tan	10.0	25.0	10.0	20.0
	Light brown	0.0	30.0	0.0	25.0

[1] The 20 carcasses with the highest hedonic ratings for aroma of subcutaneous fat.
[2] The 20 carcasses with the lowest hedonic ratings for aroma of subcutaneous fat.
[3] The 20 carcasses with the highest hedonic ratings for flavor of primal cuts.
[4] The 20 carcasses with the lowest hedonic ratings for flavor of primal cuts.
[5] Subjective ratings completed prior to stratification via aroma or flavor scores.

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PR-2748

Chemical Shearing of Sheep And Angora Goats

Maurice Shelton

The difficulty of getting the animals sheared is one of the problems of the sheep and Angora goat industry. Research workers have long had the goal of identifying a chemical or drug which could be administered to cause the animal to shed the fleece in a manner to facilitate removal by hand or by automated mechanical procedures. In recent years, the medical profession has identified a number of compounds for use in cancer therapy, which have the property of inhibiting cell division. Loss of hair was a frequent side effect of the use of these drugs. Wool fiber is a continuously growing tissue, and when cell division is stopped, there is a "break" in the fiber. A common example is the loss of wool which occurs when the animal has had a period of fever. Associating these phenomena, personnel of the National Institute of Health and the USDA tested one of these drugs, Cyclophosphamide,[1] on animals. Results were very encouraging in terms of the drug's ability to cause shedding of the fleece or hair cover.

Several studies have been conducted with Cyclophosphamide at the McGregor Center on sheep and Angora goats. These studies have generally dealt with identification of the effective level, the toxic levels, and the influence of the drug on the reproductive processes.

Dose Level

A dose level of 30 milligrams of Cyclophosphamide per kilogram of body weight is highly effective in causing a break in the fiber production of both sheep and Angora goats. A dose level of 20 to 25 milligrams/kilogram is sometimes effective in breaking the fiber but in other individuals will only weaken the fiber. There seems to be sufficient variation among individuals to make the response to these levels variable. Goats may require a slightly higher dose level than sheep, but the weight of the fleece on the unshorn Angora goat is a major factor in their weight and thus makes calculation of the dose somewhat more complicated.

Adverse Side Effects and Toxic Levels

A drug of this type which interrupts cell division not only does so in the case of the wool fiber, but in other tissues as well. The distinction is that a temporary cessation in growth will cause a break in the wool fiber but will have only minimal effects on the other tissues. A dose level of 30 milligrams/kilogram will cause a temporary or transitory reduction in the white cell count of some animals. At this level of toxicity the adverse effects on other tissues would be temporary. However, large scale studies which would identify more insidious effects have not been completed. One would suspect that the drug would adversely affect the fetus of the pregnant female, but no data to substantiate this effect in sheep or goats have been obtained. Limited data to date have failed to show any effect of 30 milligrams/kilogram on the estrus cycling of the female.

Toxicity studies have been completed at the McGregor Center only with male goats. In these studies, based on 30 days of observation in confinement, male goats survived 80 milligrams/kilogram, but two of three failed to survive 100 milligrams/kilogram. However, even the lower dose levels appeared to have a debilitating effect on the animals as several died of exposure or other complications when they were turned to pasture after 30 days.

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[1] A product of Bristol Laboratories, Syracuse, New York.

Possible Applications

Although the drug is extremely effective for the original goal of causing a break in the fiber, serious problems are encountered in attempting to put this method into commercial practice. Most of these difficulties derive from the fact that the break in the wool fiber occurs subcutaneously at the base of the wool follicle, and the fiber cannot be removed until new growth has forced it to the surface. The first problem is that the rate of fiber growth is not the same on different parts of the body or for different animals. Thus, some degree of shedding or loss of fibers usually occurs before the entire fleece can be removed from one individual animal or from all the animals in the flock. Blanketing the animal will help somewhat to overcome the shedding. Another possible solution is to use a lower dose (on the order of 20 to 25 milligrams/kilogram) to cause a weakening rather than a complete break. This has been done successfully with individual animals, but on a flock basis it may be unworkable because of variation between individuals or groups of animals. The problem of shedding is much more severe with Angora goats because individual locks are lost, whereas in sheep the fleece tends to hold together as a unit.

The second problem is that when the fleece is removed by this procedure, the animal's skin is left bare. With little protection from the elements, the animal is more vulnerable to freezing, sunburn and abrasions to the skin. In a healthy, vigorous animal, regrowth in 2 to 3 weeks may be adequate to provide cover. However, in those cases where regrowth is slow due to old age, poor nutrition or nutrient demands for gestation or lactation, the development of a protective cover may be delayed for an extended period of time. Still another problem is that a minimum of at least 2 workings is required to remove the fleece chemically. Once the drug has been administered, the date of removal is fixed at approximately 10 days later. In many cases, it may be necessary to house the animals to prevent the wool's being wet at the time of removal.

Because all of the complications enumerated are more serious with Angora goats than with sheep, the general conclusion is that this drug holds little promise at present for routine commercial use with this species. However, if the drug received clearance by the Food and Drug Administration, it would find immediate use with sheep. The extent of its use would be determined by balancing the difficulties from use of the drug with the difficulty of getting the sheep sheared. At present, it appears that its use would be largely restricted to farm flocks where housing or shelter is available and where shearers are relatively unavailable at costs which can be tolerated. If the present trend continues, this situation may apply to all the major sheep producing areas. Hopefully by the time this point is reached, the technique for use of Cyclophosphamide can be improved.

PR-2749

Evaluation of Certain Anthelmintics For Treatment of Internal Parasites Of Sheep and Angora Goats

MAURICE SHELTON

Control or treatment for internal parasites remains a major area of concern for producers of sheep and Angora goats. Regardless of the sanitary procedures employed, most producers eventually find it necessary to treat all or a portion of their flock and, thus, face a choice of anthelmintic. Ideally, the drug chosen should be safe, effective, readily available (including approval by the Food and Drug Administration) and relatively inexpensive. Earlier reports (Shelton and Engelking, 1967 and Shelton *et al.*, 1968) have identified drugs or preparations which possess certain of these qualities, but not one which possessed all of them. It is generally believed that the more troublesome internal parasites have developed a resistance to phenothiazine and thiabenzole, the more widely used preparations. Studies at the McGregor Center have shown Ruelene to be a highly effective anthelmintic but to possess a low margin of safety. These studies have also shown Loxon to be highly effective and to possess acceptable safety margins, but this product has not yet received FDA approval for marketing. The present study compares some of these drugs with a still newer product, levamisole[2]. Three trials were conducted with sheep and goats using egg counts before and after treatment as a gauge of effectiveness. The drugs involved were thiabenzole, phenothiazine, Ruelene and levamisole. In addition, toxicity trials were conducted with levamisole on both sheep and Angora goats.

Trial 1

Trial 1 was conducted in July 1969 and involved 88 ewe lambs averaging 72.2 pounds. The treatments employed and results obtained are shown in Table 1. Initial counts and treatments were made July 9. Subsequent egg counts were made 1 week later, July 16. The treatments involved phenothiazine, thiabenzole, Ruelene, levamisole and combinations of Ruelene with phenothiazine or thiabenzole. Some preliminary experience had suggested mixtures of this type to be highly effective without approaching a toxic level of Ruelene. In this trial, levamisole appeared to be most effective with Ruelene or a combination of Ruelene and thiabenzole only a little less effective. Neither phenothiazine nor thiabenzole, particularly at the lower level, was highly effective.

Trial 2

This trial was conducted with 35 yearling Angora

[2] 1-2, 3, 5, 6-Tetrahydro-6-phenylimidazo [2,1-6] thiazole hydrochloride marketed in this country by American Cyanamid under the trade name Tramisol.

TABLE 1. RESULTS OF DRENCHING EWE LAMBS WITH VARIOUS ANTHELMINTICS

Treatment drug and level[1]	Number lambs	Average weight, pounds	Eggs per gram Initial 7/9	Eggs per gram Final 7/16	Final as percent of initial 7/9	Final as percent of controls 7/16	Percent[2] efficacy
Control	11	70.3	7790	11,113	142.6		
Phenothiazine, 1 ounce	4	65.8	3375	1187	35.2	19.8	64.8—80.2
Phenothiazine, 2 ounces	10	81.0	5410	1605	29.7	26.8	70.3—73.2
Thiabenzole, 1 ounce	4	71.3	2225	1475	66.3	24.6	33.7—75.4
Thiabenzole, 2 ounces	10	69.0	5890	1243	21.1	20.7	78.9—79.3
Ruelene, 15-20 cubic centimeters	10	75.2	3270	162	5.0	2.7	95.0—97.3
Thiabenzole + Ruelene[3]	10	77.3	7720	475	6.2	7.9	93.8—92.1
Phenothiazine + Ruelene[3]	10	69.6	2850	1902	66.7	31.8	33.3—68.2
Levamisole, 8 milligram per kilogram	10	70.6	11,630	30	0.0	0.5	100.0—99.5

[1] Phenothiazine, thiabenzole and Ruelene were used in the form of standard commercial formulations, and dosages are expressed in volume of preparations.

[2] The two values are based on the two preceding columns and depend on which value (initial for the individual lot or final for the controls) is used as a standard. Data in Tables 2 and 3 are presented in similar manner.

[3] These two lots were drenched with mixtures of 1 ounce thiabenzole or phenothiazine and one-half the normal dose of Ruelene.

TABLE 2. RESULTS OF DRENCHING YEARLING ANGORA DOES

Treatment drug and level	Number goats	Weight	Eggs per gram Initial 7/30	Eggs per gram Final 8/6	Final as percent of initial 7/30	Final as percent of controls 8/6	Percent efficacy
Control	5	63.4	5720	2940	51.4		
Thiabenzole, 1½ ounce	6	68.7	3492	133	3.8	4.5	96.2—95.5
Phenothiazine, 1½ ounce	6	59.7	3888	808	20.8	27.5	79.2—72.5
Ruelene 10-12 cubic centimeters	6	60.2	2308	267	11.6	9.1	88.4—90.9
Levamisole ½—¾ ounce	6	65.2	3150	13	0.4	0.4	99.6—99.6

does averaging 63.4 pounds. Initial counts and treatments were made July 30 with subsequent counts 1 week later on August 6. The drugs employed were the same as those used in Trial 1 with the exceptions: only one level of phenothiazine and thiabenzole was used; no combinations were used. The results, Table 2, again show levamisole to be most effective with both Ruelene and thiabenzole giving creditable results. Again, phenothiazine apparently failed to remove as many of the gastrointestinal nematodes.

Trial 3

This trial involved 29 small "tail ender" ewe lambs from a larger group of 150 lambs. These lambs averaged 58.3 pounds. The original counts were made and treatments applied September 26 with subsequent counts made 1 week later on October 3. The treatments employed were the same as those used in Trial 2. The results, shown in Table 3, again show Ruelene and levamisole to be highly effective and phenothiazine and thiabenzole to be less effective.

The four anthelmintics were used at comparable levels (considering body weight variations) throughout the three trials. Results from the three trials are summarized in Figure 1 to show relative effectiveness of the anthelmintics. Phenothiazine and thiabenzole remain partially effective, and, in addition, the safety of both drugs is well recognized. In both, the dose levels

TABLE 3. EFFICACY OF FOUR ANTHELMINTICS FOR REMOVAL OF INTERNAL PARASITES OF FINE-WOOL EWE LAMBS

Treatment drug and level	Number lambs	Average initial weight	Eggs per gram Initial 9/26	Eggs per gram Final 10/3	Final EPG as percent of original	Final EPG as percent of control 10/3	Percent efficacy
Control	5	57.6	1140	4310	378.1		
Thiabenzole 1½ ounce	6	52.7	975	358	37.4	8.3	62.6—91.7
Phenothiazine 1½ ounce	6	59.5	1167	392	33.6	9.1	76.4—90.9
Ruelene 14 cubic centimeters	6	63.2	1368	33	2.4	0.8	97.6—99.2
Levamisole, 8 milligrams per kilogram	6	58.7	1283	33	2.8	0.8	97.2—99.2

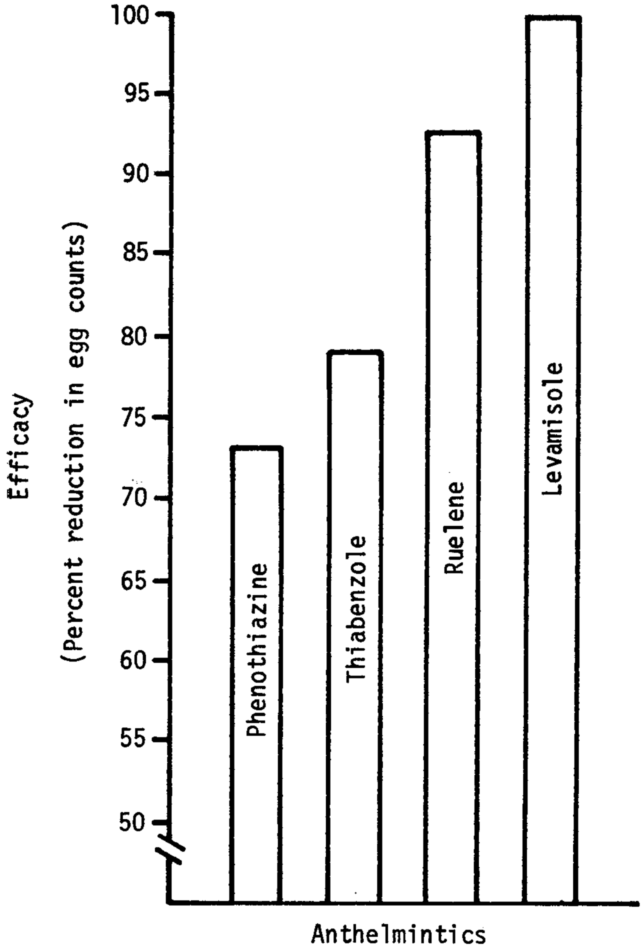

Figure 1. Relative effectiveness of the four anthelmintics tested.

were approximately doubled over label direction. The development of resistance to these drugs is generally considered to be the cause for less than optimum results; it is realized that the degree of parasite resistance may well vary with conditions and the amount of past use of these drugs on a given property. Thus, producers would be advised not to automatically discard these two anthelmintics, but to do so only when they no longer give the desired results. When this point is reached, both Ruelene and levamisole, shown by these studies to be highly effective, are possibilities. The effectiveness of Ruelene has previously been established but it has not received widespread use because of a low margin of safety. Thus, these studies indicate levamisole as a potentially valuable new anthelmintic.

These studies involve only fecal egg counts which do not provide direct information on the actual numbers or species of internal parasites. However, earlier, studies at the McGregor Center, including controlled critical trials, have shown fecal egg counts to be a reliable means for evaluating materials to be used as a general anthelmintic for mixed injections. Other studies reported in the literature have shown levamisole to be effective against the more common adult gastrointestinal nematodes of sheep. A limited number of critical trials involving levamisole have been conducted at this center to test its effectiveness against *H contortus*, the most common intestinal roundworm of sheep. These studies show the 8 milligram/kilogram level to be essentially 100-percent effective in removing adult forms of this parasite.

Toxicity Studies with Levamisole

Since the above studies showed levamisole to be a potentially valuable new anthelmintic, two toxicity studies were conducted to determine whether this drug could be safely used with sheep and Angora goats. In the first trial, 16 Angora does were treated at doses ranging from 0 to 48 milligrams per kilogram or up to six times the effective dose of 8 milligrams/kilogram. The dosages employed were 0, 8, 16, 24, 32, 40 and 48 milligrams/kilogram with two animals receiving each dose level. All the animals survived the treatment with no evidence of toxicity except for possibly mild discomfort for the first hour or so after treatment. The second toxicity study involved nine ewe lambs which received dose levels of 0, 8, 16, 32 and 64 milligrams/kilogram. Two animals were treated at each dose level except for the 64 milligrams/kilogram-level at which only one animal was treated. All animals survived the treatment with no evidence of toxicity or discomfort. Although involving relatively small numbers, these studies seem to indicate that this drug can be used safely at the effective dose level.

Levamisole is currently being marketed by American Cyanamid under the trade name Tramisol. At present, it has FDA approval for use only with cattle with an application pending for a label for sheep.

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PR-2750

Estimate of Certain Genetic Parameters Relating to Angora Goats

Maurice Shelton and J. W. Bassett

The design of optimum breeding or selection programs for improvement of any type of farm or ranch livestock requires a knowledge or reasonable estimate of the genetic parameters for the various traits involved. The parameters of primary interest would be the economic value and heritability of the various traits, the amount of variability in the individual traits and the phenotypic and genetic correlations between the traits. Several earlier attempts to obtain these statistics for Angora goats have yielded inconsistent or unbelievable results. The present analyses were undertaken to obtain some preliminary values for use in constructing a selection index.

Materials and Methods

The data for these analyses were from 510 animals (119 males and 391 females) which were born and raised at the McGregor Center in the years 1958-67, inclusive, and on which at least partial fleece data are available. Only records of the second and third shearing (1 or 1½ years of age) are included for males, but data on females include those from animals from the age of 6 months to 7 years. However, fifty-four (54 percent) of the records on females are from the second and third shearing, and 83 percent of the data included for females were from animals 3 years of age or younger. A preliminary analysis of variance indicated that both age and sex significantly affected animal performance. The influence of age on certain traits of the Angora goat has been reported previously (Shelton, 1961 and Bassett and Engdahl, 1968), and the present analyses generally confirm the trends reported earlier. Because both age and sex were found to be significant sources of variation on the performance traits, all analyses were made within sex, age and shearing season subgroups. Since age was classified on half-year basis and kidding occurred only in the spring, age and season are completely confounded. The traits studied included body weight, grease fleece weight, clean fleece weight, yield, staple length (lock length), fiber diameter, percent kemp and medullated fibers and scores for lock type, face cover, neck cover, belly cover and amount of kemp. Staple length measurements were lock lengths taken on the animal. Clean yield and fiber diameter measurements were made at the Wool and Mohair Laboratory at College Station. All scores were assigned on a 0 to 4 basis with the higher values representing a greater amount of covering or a greater amount of kemp. Thus, high values were desirable for neck and belly covering and lower values more desirable for face cover and kemp. Generally these scores were assigned only at the first two shearings; for fleece and body weight data taken on older animals, the scores taken nearest to this age were used in correlation studies. Scores were assigned by one individual, but the same individual assigned all scores within a given season.

Phenotypic correlations were calculated on a within year, age and sex and season subgroup. Heritability values were estimated from paternal half-sib data. Genetic correlations were calculated by covariance analysis of the paternal half-sib data. All sire-sex-age subgroups with fewer than three animals were deleted from the half-sib analysis.

Results and Discussion

As indicated earlier, the majority of the data pertain to the second and third shearing. The number, means and an estimate of variance are shown in Table 1. The remainder of the data making up the 510 observations are from older does. These contributed little to the heritability analysis, however, since meaningful sire groups were not present in advanced age groups due to their small numbers. Only a few points seem to warrant special emphasis in this table. The finding that doe kids outsheared male kids at 1 year of age was somewhat surprising. The male kids, which weighed an average of 76 pounds, would have gone through a rutting period during the time this second fleece was produced, and this was possibly a factor in their low shearing weight. Neither age group received any special care or supplemental feeding, and, thus, the values should approach normal for commercial goat flocks. The coefficient of variability gives a mathematical expression of the variability within a trait expressed as a function of the mean or magnitude of the units of measure. Both yield and fiber diameter have low coefficients of variation suggesting that selection opportunities in these traits may be somewhat limited due to a lack of genotypic variation. This may also act to lower heritability for the traits concerned. Kemp, when expressed as either a score or an actual laboratory count of kemp or medullated fibers, shows a high coefficient of variation. Both these situations may be peculiarities of this particular flock and not indicative of the population in general. This flock had a higher than normal incidence of kempy individuals, but there is no reason to believe that it would be less variable than others in yield or fiber diameter. However, in a performance testing program involving animals from several flocks, some increased variation in the latter two variables would be expected.

Table 2 shows the phenotypic and genotypic correlation among traits of Angora goats. The phenotypic correlations in general are surprisingly low except for traits which represent alternative measures of the same variable. As expected, grease and clean weight are highly correlated, and neck cover and belly cover are highly correlated. The otherwise low values are probably due partially to the fact that those represent pooled values collected over two sexes, several ages and several seasons. Body weight was significantly related to clean weight, but not grease weight. Body weight was negatively related to face, neck and belly cover with face covering being more important as a source of variation in body size. The relationship between size and fiber diameter was significant only at the .05 level. Both grease and clean weight were positively related to fiber diameter, staple length and all measures of body cover.

The genetic correlations are theoretically limited by plus or minus one, but because of the way they are calculated, they are not so restricted. In the present study, several values exceeded one. Since this cannot be correct, they have been entered in Table 2 as 0.750 which is considered a practical upper limit. These values have all been italicized to show this artificial entry. In each case they carry the correct sign. Consistent negative values were obtained for all values relating to mohair production and body weight. This

TABLE 1. INFLUENCE OF AGE AND SEX ON MEANS AND VARIATION OF CERTAIN TRAITS OF ANGORA GOATS

	Males					Females				
Trait	Age, years	Number animals	Mean	SD	Coefficient of variation	Age, years	Number animals	Mean	SD	Coefficient of variation
Body weight, pounds						0.5	32	45.4	8.05	.177
	1.0	20	76.2	14.3	.187	1.0	100	51.2	10.8	.211
	1.5	33	84.7	12.3	.146	1.5	39	63.7	9.39	.147
Grease weight,						0.5	32	3.11	.536	.172
pounds	1.0	73	3.95	1.11	.280	1.0	172	5.35	1.30	.243
	1.5	43	8.07	1.23	.153	1.5	41	6.54	.970	.148
Clean weight, pounds						0.5	32	2.40	.467	.194
	1.0	73	3.02	.767	.254	1.0	172	4.08	1.00	.246
	1.5	43	6.32	1.03	.163	1.5	41	5.18	.809	.156
Yield, percent						0.5	32	77.2	5.09	.066
	1.0	73	76.6	5.08	.066	1.0	174	76.6	5.74	.075
	1.5	43	78.3	4.68	.060	1.5	41	79.3	4.81	.061
Fiber diameter,						0.5	32	28.0	1.80	.064
microns	1.0	73	29.6	2.42	.082	1.0	174	32.2	3.86	.120
	1.5	43	40.2	3.07	.076	1.5	41	35.6	3.66	.103
Medullation, percent						0.5	22	.740	1.95	2.63
	1.0	53	1.81	2.15	1.19	1.0	111	1.30	1.81	1.39
	1.5	6	1.33	1.51	1.13	1.5	33	.970	2.16	2.23
Kemp, percent						0.5	22	.827	2.38	2.87
	1.0	53	.528	1.08	2.05	1.0	95	.712	1.11	1.56
	1.5	6	.167	.408	2.44	1.5	33	.727	1.13	1.55
Staple, centimeter						0.5	32	13.5	1.37	.101
	1.0	73	11.6	2.00	.173	1.0	174	13.0	1.91	.146
	1.5	43	13.7	1.78	.130	1.5	41	13.0	1.65	.126
Face cover score						0.5	32	1.53	1.08	.703
	1.0	73	1.04	.824	.792	1.0	122	1.58	.955	.604
	1.5	42	1.40	.939	.671	1.5	41	1.78	1.13	.634
Neck cover score						0.5	32	2.84	.808	.285
	1.0	73	2.45	.867	.354	1.0	172	2.87	.639	.223
	1.5	43	2.60	.583	.224	1.5	41	3.20	.558	.174
Belly cover score						0.5	32	3.03	.861	.284
	1.0	73	2.60	.777	.299	1.0	168	2.98	.656	.220
	1.5	43	2.74	.581	.212	1.5	37	3.35	.633	.189
Kemp score						0.5	32	.501	.622	1.24
	1.0	73	1.27	.838	.660	1.0	171	1.51	1.01	.669
	1.5	43	1.37	1.00	.729	1.5	41	.829	.863	1.04

almost assuredly indicates a negative genetic relationship between body weight or body weight increase and fleece growth; this must be true when nutrient intake is limited. Surprisingly no genetic relationship was noted between fiber diameter and body size indicating that it is possible to select goats that have both good size and fine hair. However, fleece weight (grease or clean) and fiber diameter were highly positively related indicating a serious inconsistency in selecting for fleece weight and fine hair. As expected, body covering scores and fleece

TABLE 2. PHENOTYPIC (ABOVE DIAGONAL) AND GENOTYPIC (BELOW DIAGONAL) CORRELATION[1] AMONG TRAITS OF ANGORA GOATS

	Body weight	Grease weight	Clean weight	Yield, percent	Fiber diameter	Staple length	Face cover	Neck cover	Belly cover	Kemp score
Body weight		.101	.140*	.099	.128*	.041	−.354**	−.225**	−.151*	.150*
Grease weight	−.265		.896**	−.177**	.225**	.180**	.154**	.311**	.437**	−.152**
Clean weight	−.314	.800		.136**	.257**	.318**	.157**	.236**	.384**	−.115*
Yield percent	−.291	.024	.880		.129*	.439**	.020	−.163**	−.112*	.072
Fiber diameter	0.000	*.750*	*.750*	−.017		.109*	−.067	.096	.110*	−.065
Staple length	−.321	−.329	.020	.900	−.863		.098	−.107*	.025	.166**
Face cover	.058	*.750*	*.750*	*.750*	*.750*	.717		.263**	.246**	−.051
Neck cover	−.398	.758	.248	−*.750*	.919	−.794	−.320		.596**	−.215**
Belly cover	−.555	*.750*	*.750*	−*.750*	*.750*	−.960	*.750*	*.750*		−.181**
Kemp score	−.504	−*.750*	−*.750*	.766	−.685	.159	−.931	−.502	−*.750*	

* Indicates statistical significance at the .05 level of probability.

** Indicates statistical significance at the .01 level of probability.

[1] It is not possible to calculate statistical significance of genetic correlations as was done with phenotypic correlations.

weight are highly related. By contrast, staple length (lock length) was not significantly related to clean weight, but was negatively related to body cover. In this flock, kemp score was negatively related to all traits of value indicating several advantages to be gained by eliminating kemp.

Heritability estimates are shown in Table 3. In general, these values are within the ranges which might be expected and indicate that good progress could be expected from selecting for most traits. The estimate for staple length seems unusually high. Since the values used here represent lock length, these values represent lock type as much as fiber length, and no doubt lock type is highly inherited and thus has influenced the estimate reported. An earlier report (Shelton, 1965) has shown that actual fiber length has a higher relationship to mohair production, but is lower in heritability than lock length. Heritability estimate obtained for belly covering was near zero. The reason for this is not clear, but one possible explanation is that the relatively small amount of effort expended in collecting belly covering scores resulted in a poor job of scoring this trait.

The relatively low heritability estimate obtained for fiber diameter was disappointing. A heritability of this magnitude would indicate that only slow progress can be expected from selection for this trait. There is no reason to suspect that this is not a correct value as applied to this population. However, as pointed out earlier, there was rather small variability in this trait in this population, and in a population with a wider genetic base a greater opportunity to select for fiber diameter might be provided. More genotypic variability in this trait would likely also result in higher heritability.

Some Indications

These genetic parameter estimates are somewhat preliminary, and it is hoped that they can be recalculated at a later date using more suitable and more adequate data. However, the present study does appear to warrant some definite conclusions.

The high negative genetic relationship between grease fleece weight and body weight or body weight increase faces producers with a serious paradox. It is well established that adequate *size or development* is an *absolute necessity* for good reproduction and resistance to freeze losses, abortion and other factors related to vigor and survival. Recent nutritional investigations have shown conclusively that a small Angora, especially a breeding doe, bred for a high level or fiber production has a nutritional requirement sufficiently high that it is undernourished under all except the very best of conditions. The widespread practice of breeders of developing and selecting billies on a high plane of nutrition has contributed to development of a population lacking adaptability to conditions under which many commercial goats are raised. However, it is asking a great deal of a breeder to suggest that he choose one of the alternative courses of (a) relaxing selection for the primary character of mohair weight or (b) making selections under more practical conditions which would seriously limit his ability to sell breeding billies.

TABLE 3. HERITABILITY ESTIMATES FOR VARIOUS TRAITS OF ANGORA GOATS

Trait	Heritability, percent	Trait	Heritability, percent
Body weight	50.3	Staple length	79.2
Grease fleece weight	40.0	Face cover	30.7
Clean fleece weight	19.8	Neck cover	49.2
Yield	47.8	Belly cover	1.9
Fiber diameter	11.8	Kemp score	42.7

The absence of any genetic relationship between fiber diameter and body size suggests that selection for a large fine-haired goat is completely in the realm of possibility. The resulting animal should have longer staple (lock length) and a much wider range of adaptability. Some reduction in fleece weight, or fleece weight per unit of body weight, is almost certain to occur. If a breeder can visualize that the premium for fine-hair would be adequate to make up for the loss in fleece weight, this would appear to be the proper course of action. However, this involves a prediction of future developments in mohair markets which can never be done with complete accuracy.

Some increase in reproductive rate and survival is almost certain to accompany any increase in body size. If replacement goats are in reasonable demand, the increase in realized fertility should fully compensate for any loss in fleece weight. Increase in body size is seldom actually associated with a decrease in fleece weight, but is almost always associated with a reduction in fleece weight per unit of body weight and thus presumed nutritional efficiency of mohair production.

The low heritability of fiber diameter within the flock used in this study suggests that any rapid genetic change in hair quality may require going outside the flock to breeding lines that concentrated on this character for a period of years.

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PR-2751

Influence of Adding Calcium Hydroxide To High Concentrate Rations for Lambs

MAURICE SHELTON AND M. C. CALHOUN

The problem of acidosis of lambs on high concentrate rations is well recognized. Not only may this condition be a cause of death losses when animals are initially exposed to these types of rations, it is also thought to be a possible contributor to lowered performance throughout the feeding period. Numerous feeding trials have been conducted at McGregor Center using various buffering agents (carbonate or bicarbonate forms of calcium, sodium or potassium) in an attempt to overcome this problem. In general, these efforts have not been successful. This lack of success has tentatively been attributed to the inability to add sufficient bicarbonates to the ration to provide a significant buffering effect without lowering the palatability of the ration. Other factors, such as distension of the rumen due to the release of carbon dioxide gas on neutralization of carbonates or bicarbonates, may also be a factor influencing feed intake. This suggests the possibility that a more potent neutralizing agent such as the hydroxide forms of the above elements might be used.

Calcium hydroxide was chosen for use in these studies for several reasons. The first was that a deficiency of calcium exists in high grain rations, and supplementation with some form of calcium is a requirement. Also, calcium hydroxide is generally available in the form of slaked or hydrated lime and could be added to the ration at minimal cost as a required mineral possibly not requiring approval as a new drug. Bhattacharya and Warner (1968) reported favorable results from the use of calcium hydroxide in pelleted high concentrate rations with sheep. They suggested that this material might have an advantage over carbonates or bicarbonates as alkali forms because it does not produce carbon dioxide gas on neutralization. Earlier trials at McGregor Center using calcium hydroxide at levels approaching those employed by Bhattacharya and Warner tended to give unfavorable results (Calhoun, Shelton and Huston, 1969); this was due possibly to an adverse effect on palatability and to the filtering out of the very fine particle calcium hydroxide and its accumulating as a residue in the feed trough. Subsequently, two trials were conducted in which attempts were made to prevent these results.

Trial 1

This trial was initiated December 16, 1968, using a mixed group of feeder lambs purchased in the Central Texas area. The lambs had been on winter grain pasture for a few days before initiation of the trial and were weighed into the experiment with a fill. The basic ration was a 90-percent concentrate ration with 10 percent ground alfalfa hay as a roughage. Three percent vegetable fat and 3 percent molasses were used in an attempt to bind the calcium hydroxide with the remainder of the ration ingredients to prevent settling out and to reduce dust. In addition to a control group, other groups received treatments employing 3 percent $Ca(OH)_2$ continuously; 2 percent $Ca(OH)_2$ initially, reduced to 1 percent at the end of one week; 1 percent $Ca(OH)_2$ continuously; and 1 percent $Ca(OH)_2$ initially, reduced to 0 at the end of 1 week. All lambs were placed directly on the experimental rations without an adjustment period. The length of the feeding period was 6 weeks. The results are shown in Table 1. Calcium hydroxide tended to reduce gains with the degree of reduction related to the level of $Ca(OH)_2$ in the ration. A significant reduction in feed efficiency was evident only at the 2-percent level. It is of interest that the only case of acidosis occurred in the control lot, but with the small numbers involved, this cannot be accepted as evidence that a beneficial effect was obtained from the addition of calcium hydroxide. From these results it seems that the adverse effect was related to the level of calcium hydroxide added and that favorable results might be obtained at a lower level. At the end of the trial, a portion of the lambs had neither satisfactory slaughter condition nor weight. These were rerandomized into two groups and fed calcium hydroxide at the 0 or 0.5-percent level for a 5-week period. The results, Table 2, favored the ration containing calcium hydroxide at the 0.5-percent level, but with the small numbers involved, the differences observed would not approach statistical significance.

TABLE 2. INFLUENCE OF 0.5 PERCENT $Ca(OH)_2$ ON LAMB PERFORMANCE

Treatment	Number lambs	Losses to acidosis	Average daily gain, pounds	Pounds feed per 100 pounds gain
Control	6	0	.623	5.76
0.5 percent $Ca(OH)_2$ continuously	6	0	.647	5.40

Trial 2

In the second trial (August 23 to Nobember 15, 1969), pelleting was used as a means of preventing settling out of the calcium hydroxide. Ten percent cottonseed hulls were used instead of alfalfa hay as a roughage source. The basic or control rations used in both these trials are shown, Table 3. The treatments

TABLE 1. INFLUENCE OF VARIOUS LEVELS OF CALCIUM HYDROXIDE ON PERFORMANCE OF FEEDER LAMBS FED HIGH CONCENTRATE RATIONS

Treatment	Number lambs	Number lambs lost to acidosis	Average daily gain, pounds	Pounds feed per pound gain
Control	9	1	.671	5.36
2 percent $Ca(OH)_2$ continuously	9	0	.420	6.28
2 percent $Ca(OH)_2$ reduced to 1 percent	9	0	.512	5.16
1 percent $Ca(OH)_2$ continuously	9	0	.551	5.26
1 percent $Ca(OH)_2$ reduced to 0 percent	9	0	.606	5.31

TABLE 3. BASIC OR CONTROL RATIONS IN TRIALS 1 AND 2

Ingredient	Trial 1	Trial 2 (pelleted)
Alfalfa hay (ground)	10.0 percent	0.0 percent
Cottonseed hulls	0.0 percent	10.0 percent
Sorghum grain (dry rolled)	70.0 percent	65.5 percent
Dehydrated alfalfa meal	0.0 percent	3.0 percent
Cottonseed meal	7.0 percent	12.0 percent
Hydrolized feather meal	3.0 percent	0.0 percent
Urea	1.0 percent	1.0 percent
Calcium carbonate	1.5 percent	1.5 percent
Trace mineral salt	1.5 percent	1.0 percent
Molasses	3.0 percent	6.0 percent
Vegetable fat	3.0 percent	0.0 percent
Vitamin A	1,000 IU per pound	1,000 IU per pound
Aureomycin	15 milligrams per pound	15 milligrams per pound
Stilbestrol	1 milligram per pound	Not used

employed in addition to a control lot were 0.5 percent and 1 percent calcium hydroxide continuously. The lambs involved were surplus feeder grade lambs from the station flock. All lambs were placed directly on the trial rations, but some had had access to high concentrate rations earlier. The results are shown in Table 4. Again, 1 percent calcium hydroxide substantially reduced gain. Average daily gains for the control and 0.5-percent level of calcium hydroxide are essentially comparable with some apparent advantage in efficiency for the ration containing calcium hydroxide. The calcium hydroxide in the pelleted ration made the pellets much harder, and at the 1-percent level it appeared that this would substantially reduce rate of utilization by the lambs. At the end of this experiment, the lighter weight lambs were again rerandomized into two lots and continued on the rations containing either 0 or 0.5 percent calcium hydroxide for a periof of 4 weeks. The results, Table 5, tend to favor the ration containing 0.5 percent calcium hydroxide.

Discussion

These studies appear to bring out three points of potential interest. The first is the clearly established fact that calcium hydroxide at the level of 1 percent or greater has an undersirable effect on the performance of feeder lambs. The only statistically significant result obtained in these trials was that of the reduction in performance associated with the higher levels of $Ca(OH)_2$. This is in contrast to the results of Bhattacharya and Warner (1968) who reported favorable results at 2.5 percent of the ration. These data suggest that this material used at 0.5 percent or perhaps lower may be found to have an advantage in high concentrate rations. In two of three comparisons where it was used at this level, an improvement in rate of gain was recorded, and in all three cases in which this level was used, an improvement in efficiency was noted. These trials involved only small numbers and it would appear that the 0.5-percent or a lower level should be studied further. Calcium hydroxide in the ration definitely caused a hardening of the pellet; this information might be used to advantage by the feed industry. However, calcium hydroxide should not be routinely used as a pelleting aid because of its influence on the nature of the ration.

TABLE 4. INFLUENCE OF LOW LEVELS OF CALCIUM HYDROXIDE ON PERFORMANCE OF LAMBS FED HIGH CONCENTRATE RATIONS

Treatment	Number lambs	Losses to acidosis	Average daily gain, pounds	Pounds feed per pound gain
Control	11	0	.711	5.44
0.5 percent $Ca(OH)_2$	11	0	.696	5.17
1.0 percent $Ca(OH)_2$	11	0	.613	5.51

TABLE 5. THE INFLUENCE OF 0.5-PERCENT LEVEL OF $Ca(OH)_2$ ON ANIMAL PERFORMANCE

Ration	Number lambs	Death losses to acidosis	Average daily gain, pounds	Pounds feed per pound gain
Control	6	0	.506	6.67
0.5 percent $Ca(OH)_2$	6	0	.526	6.09

Acknowledgment

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PR-2752

Chlortetracycline and Sulfamethazine In High Concentrate Lamb Rations

M. C. Calhoun and Maurice Shelton

Low levels of an antibiotic such as chlortetracycline are generally included in lamb rations to improve growth and reduce losses from enterotoxemia. Sulfamethazine in combination with chlortetracycline has recently been approved for use in beef cattle rations during the first 28 days of the feeding period. This combination of drugs has been demonstrated to increase weight gains and reduce losses from respiratory problems.

To evaluate the possibility that the addition of

TABLE 1. COMPOSITION OF EXPERIMENTAL RATIONS

Ingredient	Roughage, percent 40	25	10
Grain sorghum (dry rolled)	40.0	55.0	70.0
Alfalfa hay (ground)	20.0	12.5	5.0
Cottonseed hulls	20.0	12.5	5.0
Cottonseed meal	7.0	7.0	7.0
Feather meal	3.0	3.0	3.0
Urea	1.0	1.0	1.0
Calcium carbonate	1.5	1.5	1.5
Trace mineralized salt	1.5	1.5	1.5
Molasses	6.0	6.0	6.0

In addition, vitamin A palmitate was included at a level to provide 1,000 IU per pound of mixed ration.

sulfamethazine to rations for lambs might similarly decrease the stress associated with getting lambs on feed, the following experiment was carried out.

Experimental Procedure

In this experiment chlortetracycline, 25 milligrams per pound of mixed ration, and a combination of sulfamethazine and chlortetracycline, both at 25 milligrams per pound, were compared with a control containing neither of the two drugs. The chlortetracycline and/or sulfamethazine were kept in the rations for the entire 56-day feeding period. One hundred and twenty Texas feeder lambs were used in this study (four replicates with 30 lambs per replicate). The lambs for replicates 1 and 2 were purchased from an auction at San Angelo in November 1968. The lambs used in replicate number 3 were obtained through the auction at Lampasas in February 1969. Replicate 4 lambs were from the flock at McGregor and were put on feed in April 1969.

The procedure followed in putting the lambs on experiment was essentially the same for all replicates. The day prior to being placed on experiment, they were ear tagged, drenched with thiabendazole and weighed. Subsequently, they were assigned to experimental groups at random and placed on feed. Initially, (7-days) they received a 40-percent roughage ration. At 8 days and continuing through 14 days, the roughage level was adjusted downward to 25 percent and finally on the 15th day, the roughage level was reduced to 10 percent.

All animals were weighed, without shrink, on each of 2 consecutive days initially, and at 2-week intervals thereafter. For the first 21 days, feed consumption was determined daily and subsequently at weekly intervals.

Rectal temperatures, obtained by using a 5-inch veterinary thermometer left *in situ* for a minimum of 3 minutes, were recorded twice a week for the first 28 days.

Results and Discussion

The percent composition of the rations fed is given in Table 1. The effect of adding chlortetracycline, alone or in combination with sulfamethazine, to lamb

TABLE 2. EFFECT OF ADDING CHLORTETRACYCLINE ALONE OR IN COMBINATION WITH SULFAMETHAZINE TO LAMB RATIONS ON PERFORMANCE OF FEEDER LAMBS IN DRYLOT

28-Day Performance Data

	Treatment: Control	Chlortetracycline[1]	Chlortetracycline and sulfamethazine[2]
Replicate 1			
Rectal temperature, °F.	104.4	104.2	104.2
Initial weight, pounds	68.9	69.7	67.2
Average daily gain, pounds per day	0.22	0.42	0.36
Pounds feed per pound gain	12.0	6.8	8.2
Replicate 2			
Rectal temperature, °F.	104.2	104.0	103.9
Initial weight, pounds	68.3	66.6	68.5
Average daily gain, pounds per day	0.20	0.35	0.37
Pounds feed per pound gain	13.1	7.8	7.8
Replicate 3			
Rectal temperature, °F.	104.5	104.3	104.1
Initial weight, pounds	71.0	70.6	69.5
Average daily gain, pounds per day	0.72	0.68	0.91
Pounds feed per pound gain	4.7	5.8	4.7
Replicate 4			
Rectal temperature, °F.	104.6	104.6	105.0
Initial weight, pounds	65.7	65.1	66.0
Average daily gain, pounds per day	0.64	0.64	0.82
Pounds feed per pound gain	5.6	5.5	4.8

[1] Chlortetracycline was added to the ration at a level of 25 milligrams per pound or 50 grams per ton.
[2] This was added at a level to provide a concentration of chlortetracycline and sulfamethazine in the mixed ration of 25 milligrams per pound.

rations on performance of feeder lambs for the first 28 days in drylot is shown in Table 2 and for 56 days in Table 3. Both summary of the data for each replicate and the average performance for the experiment are presented because the pattern of response was not similar for all replicates. In replicates 1 and 2, there was a marked increase in average daily gain and feed efficiency when either chlortetracycline or a combination of chlortetracycline and sulfamethazine was added to the ration. However, the addition of the sulfamethazine did not improve performance over that observed for chlortetracycline. In replicates 3 and 4, the chlotetracycline treated lambs were comparable in performance with the control groups, but the addition of sulfamethazine markedly improved weight gains in replicate 3 and both weight gains and feed efficiency in replicate 4.

The pattern of response was similar for the 28 and 56-day feeding periods. The use of the three rations with markedly different roughage levels, that is, 40, 25 and 10 percent, and the procedure of changing rapidly from one ration to the next were employed in an attempt to increase the stress of adaptation to the highest concentrate level and possibly to provide a more sensitive evaluation of the imposed treatments.

There appeared to be no consistent effect of treatment on average rectal temperature for the 28-day period. Two lambs died during the experiment. One lamb in replicate 1 receiving chlortetracycline refused to go on feed and subsequently died, and one control lamb in replicate 3 died three days after the switch from the 25 to the 10-percent roughage level. Death was apparently related to the sudden increase in the energy content of the ration. Although none of the lambs receiving the combination of chlortetracycline and sulfamethazine died, the small numbers of animals involved do not allow any conclusions as to the value of this combination in preventing death losses.

Under the experimental conditions described, there appeared to be a beneficial response from including either chlortetracycline or a combination of chlortetracycline and sulfamethazine in high concentrate rations for lambs. In two cases of four, the addition of sulfamethazine gave a marked response over that obtained by using chlortetracycline alone.

Acknowledgment

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TABLE 3. EFFECT OF ADDING CHLORTETRACYCLINE EITHER ALONE OR IN COMBINATION WITH SULFAMETHAZINE TO LAMB RATIONS ON PERFORMANCE OF FEEDER LAMBS IN DRYLOT

56-Day Performance Data

	Treatment		
	Control	Chlortetracycline[1]	Chlortetracycline and sulfamethazine[2]
Replicate 1			
Average daily gain, pound per day	0.43	0.52	0.46
Feed consumption, pound per day	2.83	3.07	2.88
Pounds feed per pound gain	6.7	5.8	6.2
Replicate 2			
Average daily gain, pounds per day	0.38	0.47	0.46
Feed consumption, pounds per day	2.76	3.14	2.85
Pounds feed per pound gain	7.3	6.7	6.2
Replicate 3			
Average daily gain, pounds per day	0.61	0.59	0.73
Feed consumption, pounds per day	3.81	3.99	4.29
Pounds feed per pound gain	6.2	6.8	5.9
Replicate 4			
Average daily gain, pounds per day	0.53	0.57	0.70
Feed consumption, pounds per day	3.56	3.77	4.00
Pound feed per pound gain	6.7	6.6	5.7
Average, Replicates 1, 2, 3 and 4			
Lambs, number	40	40	40
Death loss, number	1	1	0
Rectal temperature, °F.	104.4	104.2	104.3
Initial weight, pounds	68.4	68.0	67.8
Average daily gain, pounds per day	0.48	0.54	0.59
Pounds feed per pound gain	6.7	6.5	6.0

[1] Chlortetracycline was added to the ration at a level of 25 milligrams per pound or 50 grams per ton.
[2] This was added at a level to provide a concentration of chlortetracycline and sulfamethazine in the mixed ration of 25 milligrams per pound.

PR-2753

Comparison of Popped, Steam Flaked, Ground and Ground And Pelleted Sorghum Grain in High Concentrate Rations For Lambs Under Commercial Feedlot Conditions

M. C. Calhoun and Maurice Shelton

Grain sorghum is the major grain source for feeding cattle and sheep in the Southwestern United States. The utilization of sorghum grain by cattle appears to be improved by such processing methods as dry rolling, grinding, steaming and rolling, popping or heating, including micronizing, and rolling and reconstituting (Buchanan-Smith *et al.,* 1968; Totusek and White, 1968; Adame *et al.,* 1968 and McGinty *et al.,* 1967). Improvement in nutrient utilization, particularly energy, generally results in increased feed efficiency in cattle fed high concentrate rations where the starch from sorghum grain provides the major energy source (Newsom *et al.,* 1968; Totusek and White, 1968).

Sheep appear to utilize nutrients from unprocessed sorghum grain more efficiently than do cattle (National Acad. of Sci. Pub. 1684, 1969; Buchanan-Smith *et al.,* 1968; Keating *et al.,* 1965).

On this basis, it appears that processing of sorghum grain for lambs would not offer the same type of advantages in increasing feed efficiency as has been reported for cattle. However, there is some evidence that the type of processing method can influence feed consumption, rate of gain and, thus, feed efficiency (Shelton 1965; Beerwinkle *et al.,* 1968; Potter *et al.,* 1969). A commercial feedlot evaluation of popped, steam flaked, ground and ground and pelleted sorghum grain was initiated to provide additional information to lamb feeders on the value of various commercially available methods of sorghum grain processing.

Experimental Procedure

Two hundred and eighty blackface, crossbred, wether lambs were used in the evaluation conducted during May, June and July 1969. On arrival at the feed yard, they were sheared, implanted with 3 milligrams stilbestrol, vaccinated with clostridium perfringens Type D Toxoid for protection against enterotoxemia, drenched with Thiabendazole and randomly divided into four groups of 70 lambs per group. Each group was then assigned to one of the four treatments or sorghum grain processing methods: popped, steam flaked, ground and ground and pelleted.

Feed and water were provided *ad libitum.* Feed was available from both self feeders and open troughs. Initially, the lambs were given access to alfalfa hay and the 35-percent roughage starter ration. They also were provided with a molasses block. After about 2 weeks, the lambs were gradually worked onto a finisher ration containing 10 percent roughage. The percent composition of the rations used are given in Table 1.

Weights of feeds, both consumed and refused, were recorded, and the lambs were group weighed without shrink at the beginning and end of the feeding period (56 days). After the lambs were adapted to the finisher ration, five lambs from each experimental group were selected at random and weighed off the experiment. The average feed consumption data for the group up to that time were used to correct total feed consumption to reflect the removal of these lambs. Those lambs left at San Angelo, upon completion of the feeding period, were slaughtered at the Armour and Company plant in San Angelo. The five lambs removed from each group, along with representative portions of the experimental rations, were trucked to the Texas A&M University Agricultural Research Center at McGregor where they were maintained on the same rations used at San Angelo. Both water and feed were provided *ad libitum* with all feed consumed and refused weighed to the nearest 0.1 pound and recorded.

Subsequently, *ad libitum* dry matter intake and digestibility data were obtained with the lambs placed in a metabolism stall designed to facilitate the separate collection of urine and feces. This portion of the study consisted of a 7-day preliminary period during which the lambs were offered feed and water *ad libitum* in the metabolism stalls, followed by a 7-day collection period. Live weights of lambs were obtained initially, at the start of the preliminary period and at 7-day intervals thereafter, that is, at the end of the preliminary period and upon completion of the collection period.

Results and Discussion

The performance data for the lambs fed under commercial feedlot conditions at San Angelo are presented in Table 2. Either popping and rolling or steam flaking appeared to markedly increase weight gains over ground or ground and pelleted sorghum grain rations. In the case of the ground and pelleted ration,

TABLE 1. COMPOSITION OF EXPERIMENTAL RATIONS

Ingredient	Starter, percent	Finisher, percent
Grain sorghum	40.0	65.0
Cottonseed meal	10.0	10.0
Cottonseed hulls	35.0	10.0
Alfalfa (dehydrated)	5.0	5.0
Molasses	6.0	6.0
Urea	1.0	1.0
Trace mineralized salt	1.0	1.0
Calcium carbonate	1.5	1.5
Ammonium chloride	0.5	0.5

In addition to the above ingredients, vitamin A and chlortetracycline were added to provide levels of 1,000 IU and 15 milligrams per pound of feed, respectively. The calculated percentage compositions of the starter and finisher rations for crude protein and the important mineral elements were, respectively: crude protein, 14.3 and 15.8; calcium, 0.80 and 0.78; phosphorus, 0.28 and 0.33; potassium, 0.81 and 0.71 and magnesium, 0.21 and 0.23.

TABLE 2. FEEDLOT PERFORMANCE DATA FOR LAMBS FED POPPED, STEAM FLAKED, GROUND AND GROUND AND PELLETED SORGHUM IN HIGH CONCENTRATE RATIONS UNDER COMMERCIAL CONDITIONS

Criterion	Popped	Steam flaked	Ground	Ground pelleted
Lambs, number	65	65	65	65
Days on feed	56	56	56	56
Death loss	1	1	0	0
Initial live weight, pounds	69.1	68.8	67.2	68.3
Average daily gain, pounds	.477	.459	.399	.379
Feed consumption, pounds per day	3.48	3.28	3.35	2.80
Pounds feed per pound gain	7.2	7.2	8.4	7.4
Dressing percent	48.6	49.2	48.4	49.1
Feed cost per pound gain, cents	20.4	20.5	23.8	22.0

this was apparently related to a decrease in the amount of feed consumed, whereas, with the ground ration, decreased performance was apparently due to decreased efficiency of feed utilization.

The analyses of percent dry matter and protein and the energy content of the rations fed, along with the experimentally determined digestiblity coefficients, are shown in Table 3. The crude protein contents of these rations are considerably greater than would be recommended for use under commercial conditions. However, these were included at this level to negate arguments that protein level limits performance when ruminants are fed sorghum grain processed to increase the digestible energy content.

In this study, no increase was observed in the digestible energy content of the ration when the sorghum grain was processed by dry heat popping or steaming and flaking. The only possibility of a difference is the slightly decreased digestible protein associated with the popping process. These data are consistent with previously reported digestiblity information for sheep fed sorghum grain processed by different methods

TABLE 3. EFFECT OF SORGHUM GRAIN PROCESSING METHOD ON DRY MATTER INTAKE OF A HIGH CONCENTRATE RATION BY LAMBS AND APPARENT DIGESTIBILITY COEFFICIENTS FOR ENERGY AND PROTEIN

Criterion	Popped	Steam flaked	Ground	Ground pelleted
Ration composition (as fed basis)				
Dry matter, percent	90.5	90.5	90.7	90.8
Crude protein, percent	16.3	17.4	17.0	17.1
Energy, kilocalorie per pound	1959	1955	1941	1941
Dry matter intake, pounds per 7 days	18.28	18.05	14.88	13.23
Apparent digestibility coefficients				
Dry matter	77.3	77.6	76.7	77.6
Protein	68.4	70.9	71.8	70.9
Energy	76.4	76.3	75.0	76.3

(Buchanan-Smith, *et al.,* 1968) but differ from those reported for cattle which generally show an increase in nutrient digestibility when sorghum grain is treated either wet or dry with heat. Although there was no effect of processing on digestibility of nutrients, physical form of the ration as influenced by processing can markedly affect performance as is evidenced by the differences in performance obtained when lambs were fed either popped or steam flaked in contrast to ground and ground and pelleted rations.

Acknowledgment

This study was conducted at San Angelo through the cooperation of Mid-West Feed Yards, Inc., Veribest Cattle Feeders, Inc. and Newman and Bonner Feed Mill, Inc. • Veribest Cattle Feeders, Inc. supplied the sorghum grain used in the experiment and the popping and steam flaking processing. The rations were mixed and one ration pelleted at the Newman and Bonner Feed Mill. All rations were then sacked and delivered to the feed yard. Lambs were purchased and worked by Mid-West Feed Yards, Inc. and fed in their experimental pens.

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Vegetable Matter Defect in Mohair

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The presence of vegetable matter in wool or mohair has always been a matter of concern in determining market value. Excessive vegetable matter defect lowers yield of clean fiber, but of more serious consideration is the fact that it is not always possible to remove all of the defect by normal processing. It is then necessary to resort to special processing techniques or a greater use of labor, both of which involve increased costs. Mohair is generally classified as clear, light defect, medium defect or heavy defect with increasing discounts applied as defect content increases.

Vegetable Matter Defect Classification

There are no published guidelines or standards which delineate the boundaries between the various defect classifications. Classification is done by visual appraisal. In an attempt to obtain information which might help to indicate classification boundaries and also to determine the feasibility of making objective measurement determinations of vegetable matter content, samples were obtained from two wool and mohair warehouses in the Edwards Plateau in the fall of 1969. A pressure coring tube one-half inch in diameter was used to take core samples from individual bags of mohair which had been classified as to vegetable matter defect. Only one sample was taken from each bag, and each sample was analyzed individually. Results of these analyses are shown in Table 1.

These results represent only a very small sample, but they do show relatively large differences within classifications and some difference between warehouses with respect to classifications. A larger sample and over a greater area will be taken.

There appeared to be differences in the types of vegetable matter found in samples from the two warehouses. Samples from one warehouse contained a high percentage of horehound seed while the other had a high percentage of needlegrass. Differences in types of vegetable matter may be of greater importance than percent content since some types of vegetable matter are relatively easy to remove mechanically while others are extremely difficult.

TABLE 1. VEGETABLE MATTER PERCENT IN MOHAIR

Classification	Clear	Light	Medium	Heavy
Warehouse A	1.96	3.75	2.80	10.21
	2.27	1.84	4.55	7.68
	2.81	3.58	5.67	5.72
	6.60	1.22	5.70	13.33
	2.44	1.64	5.99	11.19
	0.87			12.71
Average	2.69	2.41	4.94	10.14
Warehouse B		0.94	6.35	
		1.26	13.16	
		3.18	6.58	
		1.26	8.96	
		1.54		
		1.66		
Average		1.64	8.76	

Vegetable Matter Defect Removal

Removing vegetable matter defect from mohair before shearing is possible. Ranchers can benefit to the greatest extent from removal at this time since in nearly every case mohair is sold on a "grease basis" subject to defect discounts. If the defect can be removed, then the discount will not apply. Several methods have been suggested, but only one method will be reported in this paper.

Cellulase is an enzyme which acts on cellulosic materials, the major component of vegetable matter defect. Cellulase has been used in poultry and swine rations to improve both cellulosic digestion and feed efficiency; to digest cellulosic materials and relieve discomfort due to bloating, gastric upset and colitis; and in numerous other areas. The possibility was considered that cellulase might act on the vegetable matter defect in mohair to the extent that some of it might be shed from the fleece before shearing. Of a group of Angora goats at the Texas A&M University Agricultural Research Center at McGregor, one-half were dipped in a cellulase solution and the remainder were used as control groups. Results are given in Table 2.

All goats were treated at one time and were sheared 2 weeks later. Each fleece was sampled with the three fourth-inch pressure coring tube, and duplicate samples were processed for vegetable matter analysis. There was no significant difference between the treated and control animals in any of the treatment groups. There were differences between the groups because of pasture differences.

These data indicate that cellulase is probably of little value in removing vegetable matter defect from mohair while the fleece is on the animal. There are probably several reasons. One might be that temperature, pH and particle size are important factors in the activity of the enzyme, and these would be diffcult or impossible to regulate on grazing animals. Another would be that the enzyme activity would probably cease or be severely inhibited when the fleece dried out. Other treatments, however, may give beneficial results.

Acknowledgment

The Cellulase 4000, a product of Miles Laboratories used in this study, was furnished by Uvalde Producers Wool and Mohair, Inc., Uvalde, Texas.

TABLE 2. EFFECT OF CELLULASE TREATMENT

Treatment group	Vegetable matter, percent: Control	Vegetable matter, percent: Treated
Yearling males	9.21	9.76
Doe kids	7.36	6.19
Mixed age and sex	17.31	17.66