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RESEARCH REPORTS

Sheep and Goat, Wool and Mohair–1974

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Contents

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Foreword

With increased demands for food and fiber, full utilization and efficient production from our land are essential. Sheep and goat production is essential for utilizing the forage and land in many rangeland areas of Texas. These animal industries, in combination with beef cattle and wildlife production, provide economic returns that otherwise would be lost.

This report summarizes recent progress and represents the broad spectrum of research that is required for technological advancement. Research programs of The Texas Agricultural Experiment Station are designed to determine why phenomena occur and to provide both practical results for procedures and new leads for research advancements.

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RESEARCH REPORTS

Sheep and Goat, Wool and Mohair–1974

Comparison of Rambouillet And Blackface Crossbred Ewes For Early Lamb Production in Texas

J. M. Klindt and Maurice Shelton

SUMMARY: A flock of 50 Rambouillet and 50 blackface crossbred ewes was maintained for 5 years to compare the two breeds for early lamb production. They were exposed to the rams in May and September. More Rambouillet than blackface ewes demonstrated estrus in the spring, and their conception rate was higher. Although Rambouillet fall-dropped lambs were heavier than blackface at birth, weaning weights were similar. In the fall the blackface ewes were superior in percent showing estrus and conception rate. Their lambs were heavier at birth and much heavier at weaning. On a yearly production basis the Rambouillet ewes demonstrated a higher conception rate, a better lamb survival rate but lower body weight. When the production of pounds of weaned lamb adjusted to 120 days of age was expressed as a function of metabolic weight, which is directly related to feed requirements, the blackface ewes were only 66 percent as productive as the Rambouillets. Fleece weights also favored the Rambouillet ewes.

Introduction

A year-round supply of lamb on the market requires that at least some ewes drop lambs outside the traditional spring lambing season. Recent studies confirmed that producers in Texas have a distinct advantage over the more northern areas in the ability to have ewes cycling throughout the year. To some extent producers have taken advantage of this by raising fall dropped lambs on winter grain pastures for the spring market. However, the studies were done with Rambouillet ewes, and data are needed on other crosses. The present study compared, for early lamb production, Rambouillet ewes with blackface crossbred ewes (arising from Hampshire or Suffolk rams crossed to finewool ewes) which tend to be found in flocks throughout the country.

Materials and Methods

In spring 1967 a flock of 50 head of Rambouillet and 50 blackface crossbred ewes was established by the Texas Agricultural Experiment Station at McGregor, Texas. The Rambouillet ewes were obtained primarily

from one range flock near Menard, Texas. The crossbred ewes were obtained from Ohio State University, but they had been purchased through commercial channels from the West.[1] The ewes were exposed to rams in May and September with the matings at both periods recorded by use of marking harness on the rams. These dates are referred to as spring and fall matings, but September at the McGregor location is actually a late summer type of environment, and this should be kept in mind in evaluating the results. This regime was continued for 5 years (through the 1971 mating season).

Results and Discussion

Performance data by season and yearly production for the 5-year period are shown in Table 1 and Figure 1. More Rambouillet ewes exhibited estrus in May than blackface, but the difference was less than might have been expected. However, there was a greater difference in the number of ewes lambing, favoring the Rambouillet. This suggests that the crossbred ewes had a lower conception rate or did not carry the lambs through the summer. Birth weight of lambs favored the Rambouillet in fall-dropped lambs but favored the crossbred ewes for spring-dropped lambs. This phenomenon along with the poorer lambing from spring mating for the crossbred ewes is probably an expression of their poorer adaptation to high summer temperatures. The crossbred ewes did not persist in the flock as well as Rambouillet. Major causes for their removal were death and failure to lamb 2 years in succession. A major cause for removal of the Rambouillet was large teats and damaged udders. Crossbred ewes were larger at the beginning of the study and remained so. Lambs from crossbred ewes had a lower survival rate but grew faster than those from the Rambouillet ewes.

Rambouillet ewes produced and weaned more lambs and more pounds of lamb. When the latter is expressed as a function of body weight and particularly metabolic weight, which is directly proportional to nutrient requirements, the difference favoring the Rambouillet was marked.

These data refute the generally held impression that crossbreeding is always advantageous. Appar-

[1] A duplicating flock of both types of ewes from the same sources was also established by the Ohio Agricultural Experiment Station at Wooster, Ohio. The original intent was to compare the flocks at both locations. However, the management schemes for the two flocks differed sufficiently over the years to make direct comparison of the data impossible.

TABLE 1. SUMMARY OF THE PRODUCTION PERFORMANCE OF RAMBOUILLET EWES AND BLACKFACE CROSSBRED EWES (MEANS OF THE YEARLY VALUES ± STANDARD ERROR OF THE MEAN), 1967-71

	Spring breeding		Fall breeding		Yearly production	
Breed of ewe	Rambouillet	Blackface	Rambouillet	Blackface	Rambouillet	Blackface
Ewes, number	39.6 ±3.1	35.6 ± 4.3	10.0 ± 1.3	17.6 ± 7.5	39.6 ±3.1	35.6 ±3.3
Average weight, lb	120.2 ±8.1	137.9 ± 9.4	121.0 ± 8.2	133.6 ± 8.8	120.2 ±8.1	137.9 ±9.4
Ewes showing estrus, %	90.4 ±2.2	82.3 ± 4.4	48.6 ±12.5	60.3 ±17.8	95.6 ±1.8	95.7 ±2.3
Ewes lambing, %	75.6 ±3.8	55.3 ±12.7	33.1 ±11.6	50.0 ±18.2	83.9 ±4.3	78.6 ±6.2
Lambs born, number	40.2 ±3.0	25.8 ± 6.8	5.4 ± 2.0	15.2 ± 7.8	45.8 ±4.0	41.0 ±6.6
Average birth weight, lb.	7.3 ±0.2	6.7 ± 0.6	7.8 ± 0.5	8.3 ± 0.4	7.3 ±0.1	7.2 ±0.4
Lambs weaned, number	28.2 ±3.3	14.8 ± 3.9	3.6 ± 1.7	8.0 ± 5.9	31.8 ±3.7	22.8 ±3.8
Average weight, lb	61.8 ±3.9	62.3 ± 4.5	48.2 ± 7.7	60.5 ±10.3	60.6 ±3.6	59.1 ±5.0
Average weight/day of age	0.63±0.06	0.69± 0.10	0.60± 0.07	0.89± 0.27	0.63±0.06	0.63±0.05
Lambs born/ewe present at breeding, number	1.02±0.03	0.80± 0.20	0.54± 0.17	0.85± 0.32	1.16±0.05	1.16±0.16
Lambs born/ewe lambing, number	1.35±0.05	1.36± 0.12	1.38± 0.37	1.30± 0.34	1.38±0.06	1.44±0.10
Lambs weaned/ewe present at breeding, number	0.71±0.07	0.45± 0.11	1.38± 0.15	0.36± 0.21	0.78±0.07	0.68±0.08
Lambs weaned/ewe lambing, number	0.94±0.06	0.74± 0.11	0.69± 0.29	0.52± 0.24	0.95±0.05	0.81±0.06
Lambs weaned/ewe present at breeding, lb.	48.2 ±7.3	27.9 ± 7.2	16.8 ± 7.5	18.2 ±10.3	48.9 ±5.9	37.1 ±4.2
Lambs weaned /ewe lambing, lb.	57.8 ±6.0	47.6 ± 8.7	32.5 ±13.6	29.2 ±12.2	56.3 ±5.5	47.7 ±5.5
Efficiency of lamb production[1]	1.62±0.26	0.79± 0.21	0.78± 0.40	0.68± 0.36	1.82±0.28	1.19±0.21
Fleece weight, lb.	---	---	---	---	9.70± .66	8.58± .71

[1] $\frac{\text{Number of lambs weaned X average weaning weight adjusted to 120 days of age}}{\text{Number of ewes present at breeding X (average ewe weight)}^{.75}}$ = Efficiency of lamb production

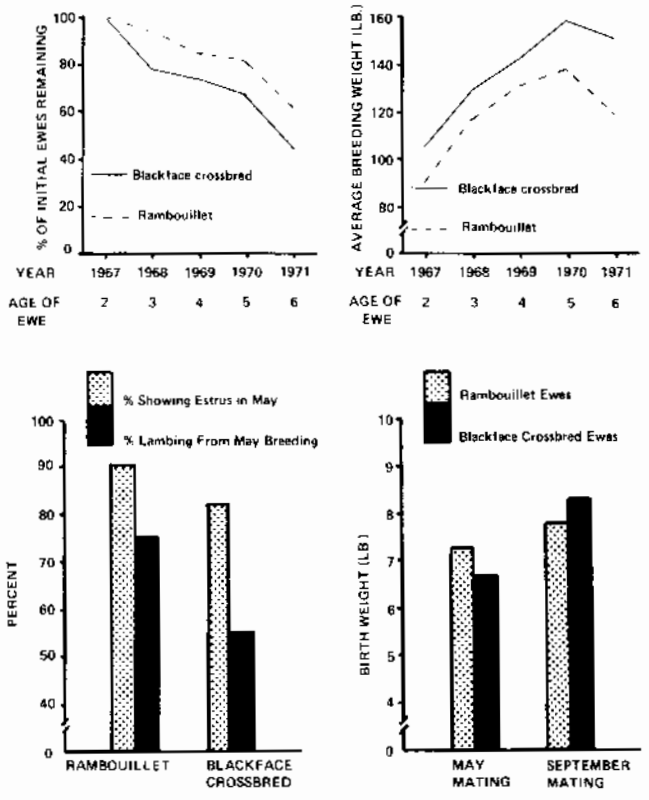

Figure 1. Influence of breed on some performance parameters of Rambouillet and Blackface crossbred ewes.

ently in this case the medium wool breeding (Hampshire and Suffolk) introduced an element of poor adaptability to the high temperature and out-of-season beeding practiced. However, these results apply uniquely to the environment or conditions involved. Numerous studies from more northern environments have shown the blackface crossbred ewe to be superior. This study points out a problem in interpretation of animal breeding comparisons. As is traditional with these types of studies, both groups of ewes were run in one band and treated alike under good feed conditions. As a result, the crossbred ewes tended to become overly fat for this type of environment. Under a regime of restricted feed intake and late fall breeding, the crossbred ewes may have performed in a manner superior to that of the present study.

PR-3284

Influence of Season On the Return to Estrus Following Lambing

J. R. Gallagher and Maurice Shelton

SUMMARY: Accelerated lambing is a potential means of improving reproductive efficiency in sheep. The effect of season and parturition on estrual cycling as a factor affecting this potential was studied in Rambouillet ewes maintained in dry lot at the Texas Agricultural Experiment Station at McGregor. The ewes were bred at the four seasons on a 9-month schedule; they were run with vasectomized rams for 75 days following lambing to allow for estrus detection. Following lambing the minimum postpartum anestrous period was 40 days. If this period extended into the ewe's normal seasonal anestrus, rebreeding difficulties occurred. These data suggest that ewes which lamb in late summer, fall or early winter may be rebred with reasonable success. However, ewes which lamb in late winter and spring are not likely to rebreed with any degree of success until the end of the spring anestrum.

Introduction

Improving productive efficiency through accelerated lambing would be of economic value to most sheep producers. The effect of season and parturition on estrual cycling is a critical factor affecting the potential for accelerated lambing. It is known that these factors are interrelated to some degree, and an understanding of this interrelationship is imperative to planning successful accelerated lambing programs. A cooperative study between the Texas Agricultural Experiment Station and the U.S. Department of Agriculture at Dubois, Idaho, provides some pertinent data.

Methods

Rambouillet ewes were bred during the four seasons on a 9-month schedule. Comparable ewes were maintained open and were checked for estrus at monthly intervals. Following lambing, all ewes were run with vasectomized rams for a period of 75 days. (That this period was fixed by other aspects of the experiment should be kept in mind in evaluating the results.)

Results and Discussion

Data are presented in Table 1 and Figure 1. Data on the open ewes were included to provide a basis for isolating seasonal anestrus from lactation or parturition anestrus. The time lapse figure for the open ewes represents the delay associated with variable stages of the estrous cycle when rams were added. However, since the check period was for 30 days and a few ewes were recorded in estrus in the latter part of the 30-day period, the reported values exceed the expected 7- to 8-day delay expected as one-half of the estrual cycle length. These data show that parturition or lactation (in this case it is not possible to isolate these two factors) does not markedly influence the percentage of ewes showing estrus but that some degree of time delay following parturition is automatically incurred. The percentage of lambing ewes showing estrus compares favorably with that of open ewes except in the case of those dropping lambs in the winter. Parturition apparently does predispose the ewe to a period of anestrus, and the length of this period appears to be markedly influenced by season of the year. The shortest anestrual period is among the ewes lambing in the fall and early winter, and the longest follows spring lambing. The percentage of ewes returning to estrus follow-

TABLE 1 RELATION OF SEASON OF THE YEAR TO EXPRESSION OF ESTRUS FOR LACTATING AND OPEN EWES

	Ewes dropping lambs[1]			Open ewes[1]		
Season	No. ewes checked	Percentage showing estrus	Average lapse in days from parturition	No.	Percentage showing estrus	Average time lapse in days from introduction of rams
Spring (Mar. & Apr.)	52	26.9	62.8	59	18.6	11.1
Summer (June & July)	50	80.0	58.8	61	50.8	14.2
Fall (Oct.)	4	100.0	39.0	32	93.7	11.5
Winter (Dec. & Jan.)	29	34.4	53.5	30	96.6	10.2

[1] Ewes which lambed by seasons were checked by vasectomized rams for 75 days post lambing, whereas the open ewes were checked only for a period of 30 days.

ing lambing in the winter is well below that of the open ewes. This apparently can be explained by the fact that in this case the parturition anestrum extends into the seasonal anestrus for many of these ewes.

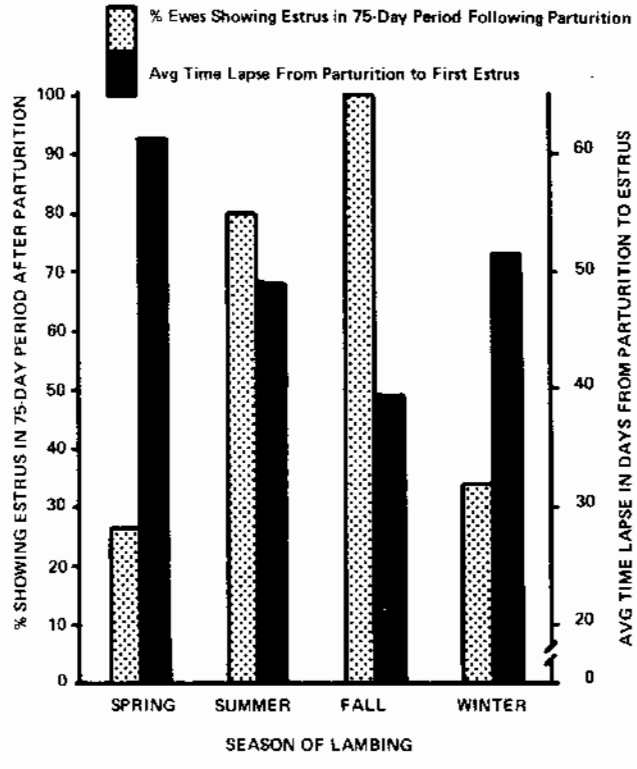

Figure 1. Influence of season of parturition on return to estrual cycling.

Conclusion

These data, along with other supporting evidence, suggest that in accelerated lambing programs ewes which lamb in late summer, fall or early winter may be rebred with reasonable success. However, ewes which lamb in late winter and spring are not likely to rebreed with any degree of success, and a single short breeding period under these conditions should be avoided.

PR-3285

Hormonal Control Of Reproduction in Sheep

Maurice Shelton and J. M. Klindt

SUMMARY: With an ultimate goal of controlling reproduction in sheep a series of studies evaluated two types of progestin: intravaginal pessaries containing 20 milligrams flurogestone acetate and subcutaneous implant containing 375 milligrams progesterone; and three gonadotrophin preparations: PMS (pregnant mare serum), HCG (human chorionic gonadotrophin) and PMS+HCG (50:50) for the induction of estrus in anestrous ewes. The gonadotrophins were injected at the rate of 750 international units (IU) at the cessation of 14 days of progestin treatment. No differences were observed between the two progestin preparations. However, distinct differences were observed among the gonadotrophin preparations. The percentages of the ewes showing estrus were 91.9, 63.6 and 79.3 for the PMS, HCG and PMS+HCG groups, respectively. In the same groups the percentages of the ewes pregnant and number of embryos per pregnancy were 51.9, 1.79; 13.0, 1.00; and 5.0, 1.00, respectively. These data indicate that the choice of progestin would be determined by cost and convenience and the choice of gonadotrophin would be PMS.

Introduction

Control of reproduction in sheep has been a long term goal of researchers. Efforts have been directed toward obtaining satisfactory breeding performance during the anestrous season and/or increasing the level of twinning at each parturition. Earlier studies showed that a period of progestin therapy (to precondition the tract or synchronize the estrous cycle) followed by an injection of gonadotrophin (to stimulate ovulation) is necessary to control or stimulate the reproductive process. Even when these requirements were identified, problems still remained. No completely satisfactory method of progestin administration has been developed, and low fertility at the synchronized estrus also has been observed. The gonadotrophin of choice has been PMS (pregnant

mare serum) which has presented problems of supply, price and reliability. The present study, part of a series designed to clarify endocrine control of reproduction in sheep, compares two types and methods of administration of the progestin and two different types of gonadotrophins.

Materials and Methods

A series of studies was conducted in the spring and summer of 1973 with aged Rambouillet ewes. Methods of synchronization were intravaginal pessaries containing 20 milligrams of flurogestone acetate[1] (Cronolone) and a silastic implant containing 375 milligrams of progesterone,[2] the latter as a skin implant under the foreleg. These products are either on the market or under application at present. The gonadotrophins employed were PMS and HCG (Spencer Mead) or equal combinations of these. All dosages were 750 IU or USP (U.S. Pharmacopoeia) units. Progestin was administered for 14 days. All gonadotrophin injections were intramuscular and made at the time the implants or pessaries were removed. Control animals received no treatment. All ewes were observed for estrus following gonadotrophin injections. Some ewes were laporatomized to provide ovulation data, and some were slaughtered at 25 days plus to provide conception data. In the latter some data also were provided on ovulation rate, but only on those ewes which were pregnant and in which the residual corpus lutea from the synchronized estrus could be counted. The organization of the experiment and results obtained are shown in Table 1.

[1] Syncro-mate manufactured by G. D. Searle and Company.

[2] A Sil-Estrus implant prepared by Abbott Laboratories and provided by the company for use in these studies.

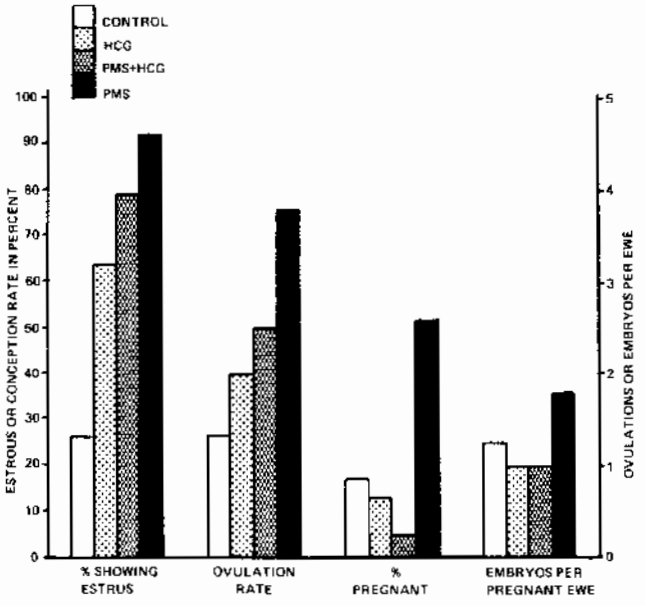

Figure 1. Influence of gonadotrophin treatment on some reproductive parameters.

Results and Discussion

These data provide little basis for making any distinction between the types of progestin treatment employed. Both gave good results when used in connection with the more desirable gonadotrophin treatment. The choice of progestin would be dictated by cost or convenience. Some problem was encountered in loss of the skin implants, but this may have resulted from lack of experience in their use.

Endocrine treatment markedly stimulated reproductive activity over the controls; however, results varied among gonadotrophin treatments. Since the progestin used did not significantly influence the results, gonadotrophin treatments have been combined for both progestin treatments (Figure 1). PMS gave far

TABLE 1. THE INTERACTION OF PROGESTIN AND GONADOTROPHIN TREATMENT ON VARIOUS REPRODUCTIVE PHENOMENA

				Ewes laporatomized			Ewes slaughtered		
Synchronization treatment	Gonadotrophin treatment	No. ewes	Percentage showing estrus	No.	Percentage ovulating	Ovulation rate per ewe ovulating	No.	Percentage pregnant	No. embryos per ewe pregnant
Progesterone implant	PMS	20	85.0	13	76.9	3.50	15	46.7	1.43
Progesterone implant	HCG	15	60.0	9	88.9	2.00	10	10.0	1.00
Progesterone implant	PMS+HCG	14	78.6	8	100.0	2.63	10	10.0	1.00
Cronolone pessaries	PMS	17	100.0	9	88.9	4.13	12	58.3	2.14
Cronolone pessaries	HCG	18	66.7	10	90.0	2.00	13	15.4	1 00
Cronolone pessaries	PMS+HCG	15	80.0	12	100.0	2.42	10	00.0	0.00
Control	Control	38	26.3	13	46.2	1.33	22	29.1	1.57

superior results: 51.9 percent of ewes treated with PMS conceived at the synchronized estrus with an average of 1.79 embryos per ewe pregnant. By contrast HCG, even when used in combination with PMS, largely blocked conception. It did produce ovulation, even though the ovulating response did not equal that of PMS. Evidently something was awry in ewes brought into estrus by the use of HCG. At this stage the reason is speculative. Since HCG contains primarily LH-like activity, the ova possibly are being ovulated in an immature state; some time delay between cessation of progestin therapy and HCG injection would appear to warrant investigation.

PR-3286

A Simple Method Of Male Sterilization For Use With Sheep and Goats

Maurice Shelton and J. M. Klindt

SUMMARY: Epididymectomy is a relatively simple method of sterilization of male sheep or goats which allows them to remain sexually active and to continue horn development. The tail of the epididymis is exposed through a 1-inch longitudinal incision of the scrotum, excised and cauterized. The testicle and epididymis are returned to the scrotum, and the incision is closed.

Introduction

At times producers may need to sterilize males without complete castration. Such males can be used (1) as teaser males to start cycling in ewes or does prior to the introduction of fertile males, (b) as a means of pregnancy diagnosis by identifying ewes or does still cycling after termination of breeding season or (c) as a means to permit horn development of sterilized males of animals such as Spanish goats or Mouflon or Barbado sheep carried to advanced age for sport hunting. Of several potential methods of sterilization, the most frequently used has been vasectomization in which the vas deferens are severed between the body and the scrotum. However, this operation is sufficiently difficult to prevent its being used routinely by producers.

In recent years several researchers have utilized epididymectomy, a procedure sufficiently simple to be routinely performed by producers. Epididymectomy implies removal of the epididymis from the lower end of the testicle. Since the epididymis is exposed and readily visible or palpable on sheep and goats, it can be removed by simple surgery. The operation is simpler and less traumatic to the animal than is surgical castration, which has been widely practiced under field conditions for centuries. Epididymectomy is not usually performed on young kids or lambs but on more mature animals of weaning or yearling age or later. However, at marking time an alternative procedure known as the short scrotum method can be used to accomplish the same goals.

Procedure

The animal to be epididymectomized is secured on its back with its legs extended. The scrotum should be washed and rinsed with a disinfectant solution. The surgical procedure is shown in Figure 1. A longitudinal incision of approximately 1 inch is made over the epididymis through the epidermis, *tunica dartos* muscle and the *tunica vaginalis communis* fascia layer. The epididymis is forced out through the incision, and the tail of the epididymis is exposed. A good portion of the epididymal tail is excised, and the remaining severed portion is cauterized to help insure that the epididymis does not regain patency. The cauterization or searing of the tissue can be performed with a piece of hot metal. The testicle and its epididymis are returned to the scrotum, and the incision is closed with wound clips or sutures. This procedure is performed on both testicles.

Precautions

In removing the epididymis, the sperm duct is severed in many places, but these severed ends remain open. Thus a spermatocele or sperm pool will usually accumulate at this point. It is possible for individual sperm cells to penetrate the severed end of the sperm duct leading to the penis. Experience at the San Angelo station has shown that if several of these males are exposed to a number of cycling females, an occasional conception will occur. Cauterization is a means of reducing the likelihood of this occurrence. Potential users of this procedure should be aware that animals sterilized in this manner will have normal *libido* or mating desire. The sterilized male or males may dominate the intact male and prevent his mating; or if this does not occur, their presence may provide sufficient

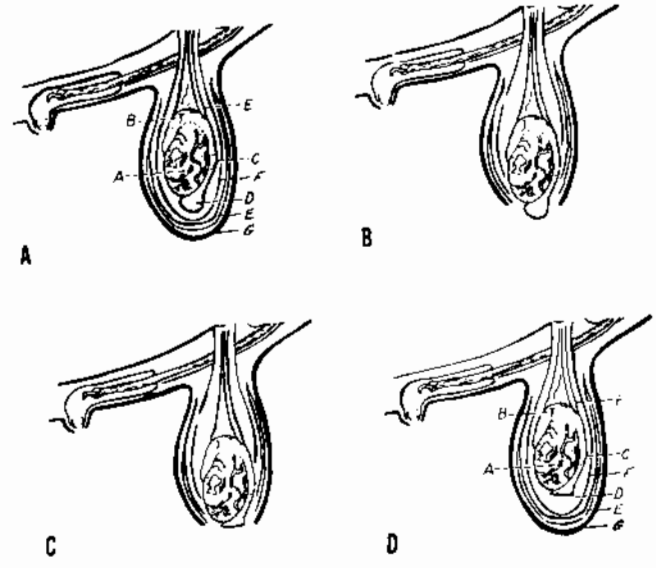

Figure 1. Steps involved in epididymectomy: (A) The intact testicle in the scrotum — *A*, testicle; *B*, head of epididymis; *C*, body of epididymis; *D*, tail of epididymis; *E*, *tunica dartoe* muscle; *F*, *tunica vaginalis communis* fascia layer; G, epidermis. (B) The scrotum with the tail of the epididymis extended through the incision. (C) The epididymis with tail excised. (D) The testicle returned to the scrotum and the incision closed.

competition to detract from mating success. Thus, though they are not fertile, the epididymectomized males should preferably be run separate from the breeding flock, especially during the breeding season. An epididymectomized male is not immediately sterile when the operation is performed. Germ cells present in the tract at the time can result in his being fertile for a period of time. Ideally, 30 days time should elapse after surgery before the male is placed in use.

PR-3287

Pregnancy Diagnosis Methods in Sheep

Maurice Shelton

SUMMARY: Pregnancy diagnosis in sheep has potential economic value for the sheep industry by permitting different management procedures for open versus pregnant ewes. Three methods for pregnancy diagnosis studied include rectal-abdominal palpation, chute sorting based on visual appraisal of pregnancy (udder palpation or body fill) and use of the ram to identify open ewes. All methods are sufficiently accurate to justify their use in specific situations.

Introduction

Pregnancy diagnosis in sheep has potential value to the industry through (1) permitting the sale of open ewes at the most advantageous time, (2) reduction in feed or grazing costs through removal and sale of open ewes as soon as possible after the breeding season, (3) savings in feed costs through alternative management of open ewes not intended for sale and (4) improved performance through better management of pregnant ewes. The latter may be particularly critical in groups such as ewe lambs where the pregnant individuals require favorable treatment.

In attempting to develop a practical method of pregnancy diagnosis in sheep, many technically workable procedures have been developed. These include radiography, use of the doppler shift principle (Shelton, 1968), vaginal cytology, progesterone assay, digital palpation through abdominal surgery and others. Because of the potential cost in equipment, time or technique, none of these have been practical for routine use by the sheep industry. The procedures have had limited use in research programs where the cost-benefit ratio is much greater. Several recent developments may make feasible the practice of pregnancy diagnosis in sheep.

Rectal-Abdominal Palpation

One of these developments, rectal-abdominal palpation (Hulet, 1972), overcomes some of the objections to earlier procedures. Under favorable conditions this technique is highly accurate after approximately 70 days of gestation and in the hands of an experienced operator is rather harmless to the ewe. It consists of placing the ewe on her back, passing a rod into the rectum and palpating for the presence of the fetus between the rod and operator's hand placed on the abdomen of the ewe (Figure 1). This technique allegedly has the potential of identifying the twin-bearing ewes but has not been adequately evaluated for this purpose.

Figure 1. The rectal-abdominal palpation procedure.

Forty-five ewes that had been exposed to a single ram through the summer to September 1 were checked by this procedure in November 1972. Sixteen ewes were identified as being open. Following checking in November, a marked intact ram was turned with the ewes. None of the ewes identified as pregnant were marked by the ram, whereas all except one identified as open were marked. This indicates a high degree of agreement between the two techniques. All of the ewes identified as pregnant lambed except one, and this ewe probably lost a lamb or lambs in the pasture. Since this initial experience, the procedure has been routinely used in experimental flocks maintained by the San Angelo station when it is important to know whether an individual ewe is pregnant; it is not routinely used on all ewes.

The time and effort required in the application of the rectal-abdominal palpation technique is similar to that required in the rectal palpation of cows which has found widespread use. Not counting the time involved in gathering sheep, a minimum of approximately 1 minute per head for two people is required for this procedure. The only equipment required is a rod approximately one-half inch in diameter and 18 inches long. If larger numbers are to be done, some type of restraining crate would be desirable. Although this seems to be a modest amount of effort, it must be placed in perspective to the probable financial gain. If it is assumed that only 5 percent of the ewes are open, which might be the case under most favorable conditions, on the order of 20 minutes mantime would be required to identify one open ewe. Under these conditions ranchers are not likely to adapt this technique as a routine practice. However, if a large portion of the ewes to be worked are open, the economics become markedly different. Thus, this technique is likely to be used when a large number of dry ewes are expected or when some other methods can be used to concentrate the open ewes.

Chute Sorting

In late gestation the majority of the pregnant ewes can be identified from udder palpation or body fill; thus, these can be removed by chute sorting. Some producers have utilized a practice of chute sorting without previous chalking of the ewes. Usually only a very slight error is found in ewes identified as pregnant by this method. However, the reverse is not true in that many ewes identified as open are pregnant. This will be true especially when the breeding season has been long, with introduction of the rams early in the season. Chute sorting of the heavy springing ewes followed by the use of rectal-abdominal examination of the remainder appears to offer a workable practice.

Use of the Ram in Pregnancy Diagnosis

To remove open ewes shortly after the breeding season is over, the use of marking harness or marking pigment on the ram can be used with a reasonably high degree of accuracy (Figure 2). Most open ewes which are in sufficiently good condition to breed will continue to cycle if they have not settled during the breeding season. These will be marked by the ram and can be removed. Among ewes which fail to mark, the only ewes not likely to be pregnant are those sick or in too poor a condition to breed; these could be checked by the recto-abdominal technique. Sometimes, pregnant ewes will be marked by the ram; these will be the occasional ewe which cycles after conception or ones erroneously marked—this can be largely prevented by proper management. Rested rams with a high degree of libido may erroneously mark one or more ewes when first placed with them. This usually can be prevented by placing him with ewes for a few hours before applying the marking pigment. In well-managed flocks the number of dry ewes should be less than 10 percent. If plans call for selling the open ewes, normal fertile rams may be used for identifying pregnant ewes. However, if plans call for keeping the open ewes, an infertile male should be used (see TAES PR-3286).

Figure 2. The use of the ram in pregnancy diagnosis. Note that the one open ewe in this group has been marked by the ram.

Between 98 and 99 percent of the remaining ewes dropped lambs when this procedure was used on a trial basis in experimental flocks. It should be remembered that this technique can be used only during the season of the year when the dry ewes are cycling.

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PR-3288

Range Versus Drylot Feeding For Preparing Low Quality Sheep For Slaughter

J. E. Huston

SUMMARY: One hundred and thirty-five low-quality lambs were divided between drylot and on-the-range feeding to investigate alternative management

methods of "problem lambs." Both groups were fed all-concentrate ration free choice. Those fed in drylot gained weight more rapidly and graded higher at slaughter. However, the estimated cost of gain was 35 cents per pound of gain for range-fed animals compared with 58 cents per pound of gain for the group fed in drylot.

Introduction

One of the stigmas of the sheep industry is the large number of lambs which do not fit into the normal pattern of fat lamb production. These include orphan lambs, undernourished twins, rejects from feedlots, crippled lambs and lambs born out of season. Alternate methods for salvaging these lambs for the industry were tested.

Experimental Procedure

One hundred and thirty-five so-called "bargain lambs" were purchased through an auction ring at a reduced price. These were a typical composite of problem lambs: ram lambs, long-age lambs and others. They were transported to pasture for 1 to 3 weeks about March 1. The lighter animals were placed on wheat pasture and the remainder on dormant native range. On March 12, the sheep were shorn, vaccinated for enterotoxemia, weighed and identified with a paint brand. Thirty-two were selected randomly and transferred to drylot at the Texas A&M University Agricultural Research and Extension Center at San Angelo. The remaining 103 were left on dormant native range in Concho County. Feed for both groups of lambs, purchased from a feed dealer in Paint Rock, Texas, consisted of 90 percent ground sorghum grain and 10 percent protein concentrate (40 percent crude protein equivalent). Feed was supplied free choice to both groups. Salt was added to the first two 1,000-pound batches taken to pasture (10 percent and 5 percent, respectively) to prevent initial overeating. Lambs taken to feedlot were hand fed the first 3 days to prevent overeating. Both groups also received 38 percent protein blocks free-choice. The sheep were marketed on three dates. Each time, the sheep were handled individually, and a judgment was made whether they would grade choice. The rule of thumb followed was that all sheep likely to grade choice were marketed. Three weights were taken when lambs were marketed: at the farm or feedlot, on arrival at packing plant (group weight) and on the following morning prior to slaughter (group weight). Carcass weights were recorded, and dressing percent was calculated. The USDA grades were recorded on the last two slaughter dates.

Results and Discussion

Five of the original 135 sheep died or were unaccounted for, while 7 others were not included in summarized data for various reasons (Table 1). Lambs marketed after having been on feed for only 16 days showed a very high apparent average daily gain (Table 2). However, the large loss of weight during transport to the packing plant is evidence of a large initial fill and expected shrink. There was a much reduced shrink in lambs marketed at later dates. Daily gains based on the weights taken at packing plant are more indicative of

TABLE 1. FATE OF PROBLEM SHEEP FED AN ALL-CONCENTRATE RATION EITHER IN DRYLOT OR ON NATIVE RANGE

Fate		Number
Range group		
Slaughtered and included in summary data		93
Omitted from data		7
Ewe sold at auction	— 1	
Ewe slaughtered but omitted	— 1	
Spring lambs omitted	— 2	
Lambs with lost carcass information	— 3	
Lambs which died		2
Lamb not accounted for		1
Total pasture		103
Drylot group		
Slaughtered and included in summary data		30
Lambs which died in feedlot		2
Total Drylot		32
Total sheep		135

TABLE 2. WEIGHT CHANGE OF PROBLEM LAMBS

Number of lambs	Days on treatment	Weights				Daily gain based on weights		
		Initial	Off feed	Arrive plant	Overnight	Off feed	Arrive plant	Overnight
Range group								
27	16	91.7	108.0	100.7	96.0	1.02	0.56	0.27
43	35	74.6	97.2	93.4	88.6	0.65	0.54	0.40
23	56	55.0	76.2	75.3	71.1	0.38	0.36	0.29
Drylot group								
8	16	87.1	106.1	100.0	95.6	1.19	0.81	0.53
12	35	78.8	93.7	92.5	88.4	0.54	0.39	0.39
10	56	60.1	89.4	88.0	84.0	0.52	0.43	0.43

TABLE 3. CARCASS DATA ON PROBLEM LAMBS

Number of lambs	Days on treatment	Carcass weight (lb.)	Dressing percent	Percent grading choice[1]
Range group				
27	16	50.7	52.8	
43	35	46.6	52.6	67.4
23	56	36.3	51.1	82.6
Drylot group				
8	16	49.9	52.2	
12	35	48.5	54.9	91.7
10	56	45.2	53.8	100.0

[1] USDA grade was not obtained on first kill date.

actual gains. Lambs fed in drylot tended to gain slightly faster (Table 2), have a higher dressing percent and grade higher (Table 3). The range group, especially the smaller lambs, did not grow and fatten as rapidly as those in drylot.

This study was a preliminary attempt to determine whether an alternative procedure could be followed in bringing "problem lambs" to acceptable market quality. Although these lambs met market standards following a period in drylot, the cost was prohibitive for most circumstances (Table 4). In this case, drylot feeding was profitable because of the initial low purchase price of the lambs. However, the much reduced cost of gain for the group fed on range suggests this method as an alternative to the feedlot for feeding lambs. A question remains as to the actual amount of range forage consumed and its value to the lamb as a source of nutrients and a roughage factor.

TABLE 4 FEED REQUIREMENTS AND ESTIMATED COST OF GAIN

Item	Range	Drylot
Total final weight	9004	2790
Total initial weight	7667	2356
Total weight gain[1]	1337	434
Sheep days	3341	1123
Average daily gain	0.40	0.39
Total concentrates	8182	5053
Concentrates per day	2.45	4.50
Concentrates per pound gain	6.1	11.5
Feed costs/pound gain		
Concentrates[2]	0.31	0.58
Range[3]	.04	
	0.35	0.58

[1] Based on weight on arrival at packing plant: represents the difference between total initial weight of lambs (including those which died) and total final weight.

[2] Based on an estimated cost of 5 cents per pound.

[3] Based on an estimated cost of 50 cents per lamb per month.

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Sorghum Grain Processing, And Roughage Source and Level For Feeder Lambs

M. C. Calhoun, Maurice Shelton, C. S. Menzies, G. C. Smith and W. W. Linderman

SUMMARY: The relative importance of sorghum grain processing methods, roughage level and quality of roughage in commercial lamb feeding was determined. Sorghum grain processing method significantly affected live weight gain (adjusted for differences in rumen fill) and feed intake of lambs. Averaged across all treatments, performance was better for dry-rolled than for whole or steam-flaked grain. The response to grain processing method was not consistent across all levels of roughage as there were significant interactions between these two factors. Dry-rolled grain gave the best performance in an all-concentrate diet, whereas whole grain worked best with 10 percent roughage. Averaged across all treatments, alfalfa hay (hammermill ground) significantly improved live weight gain and feed conversion over peanut hulls. The advantage obtained with alfalfa hay was greater at 20 percent compared with 10 percent roughage. Adjusted live weight gains were less with 20 percent roughage, though the difference was not significant. Feed intake increased with increasing roughage as did feed required per pound of gain.

Lamb performance for the various treatment combinations indicates that steam-flaked sorghum grain would be a poor choice for use in an all-concentrate diet and 20 percent peanut hulls would be undesirable in combination with whole sorghum grain.

Introduction

Processing sorghum grain by such methods as steam flaking, dry rolling, grinding, popping, micronizing or reconstitution improves neither the digestibility nor the acceptability of sorghum grain for lambs compared to feeding whole grain in high-concentrate rations (Buchanan-Smith, Totusek and Tillman, 1968; Calhoun and Shelton, 1970; Calhoun and Shelton, 1971; Calhoun and Shelton, 1972; Morris, 1966; DuBose, 1972; Billon and Edwards, 1973; Arehart, 1972a, b). However, processing methods as they influence the physical and chemical properties of grain alter both the site of utilization and end products of starch digestion with lambs (Holmes, Drennan and Garrett, 1970).

An alteration in the type of fermentation could result in a reduction of energy losses as methane and heat and in altered proportions of volatile fatty acids. Alternatively, an increase in efficiency might be achieved by processing or the feeding of whole sorghum, if a greater portion of the starch bypassed

rumen fermentation and was available for enzymatic digestion in the intestine, with a reduction in the heat of fermentation and methane, and with the production of glucose.

Recent studies with beef cattle indicate an interaction between roughage level in high concentrate diets and grain processing method (Jacobson, 1971; Preston and Hembry, 1969). Roughage quality also appears to be important, particularly with increasing levels of roughage in the diet (Calhoun and Shelton, 1973; Utley and McCormick, 1972). Thus, the optimum roughage level for use in high concentrate diets apparently is influenced by grain processing method as well as by the quality of roughage used.

Because of the potential importance of interactions among sorghum grain processing methods, roughage level and quality of roughage, these factors were combined in a single study to quantitate their relative importance in commercial lamb feeding.

Experimental Procedure

One hundred forty-four lambs, previously adapted over a 28-day period to a 10-percent roughage, high-concentrate diet, were randomly assigned to 36 pens with 4 lambs per pen. Three methods of processing sorghum grain (whole, dry-rolled and steam-flaked) and two sources of roughage (alfalfa and peanut hulls) each at three levels in the diet (0, 10 and 20 percent) were evaluated in 3 x 2 x 3 factorial arrangement of the 18 treatment combinations. Two pens of four lambs each received each of the experimental treatments.

TABLE 2. CALCULATED NUTRIENT COMPOSTION OF EXPERIMENTAL DIETS (AS-FED BASIS) [1]

	Experimental diet				
		Peanut hulls, %		Alfalfa hay, %	
Nutrient	All concentrate	10	20	10	20
Crude protein, %	12.5	12.0	11.54	12.3	12.1
Digestible protein, %	9.8	9.2	8.6	9.5	9.2
Crude fiber, %	2.6	8.4	14.2	4.7	6.8
Digestible energy, Mcal/lb.	1.58	1.48	1.38	1.54	1.49
Metabolizable energy, Mcal/lb.	1.29	1.21	1.13	1.26	1.22
Protein: energy ratio, g DP/Mcal DE	28.2:1	28.1:1	28.2:1	28.1:1	28.0:1
Calcium, %	0.84	0.78	0.73	0.81	0.79
Phosphorus, %	0.34	0.31	.29	0.31	0.31
Potassium, %	0.49	0.55	.61	0.66	0.83
Calcium: phosphorus ratio	2.5:1	2.5:1	2.5:1	2.6:1	2.6:1

[1] Nutrient values were calculated from average composition of feedstuffs reported in "Atlas of Nutritional Data on United States and Canadian Feeds." National Academy of Sciences, Washington, D.C., 1971.

The percentage ingredient composition and the calculated nutrient composition of the diets are given in Tables 1 and 2, respectively. Feed and water were

TABLE 1. PERCENT INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS

	Experimental Diet				
Ingredient, %	All concentrate	10% peanut hulls	20% peanut hulls	10% alfalfa	20% alfalfa
Sorghum grain[1]	86.5	77.0	67.4	79.6	72.6
Alfalfa hay[2]	0.0	0.0	0.0	10.0	20.0
Peanut hulls	0.0	10.0	20.0	0.0	0.0
Cottonseed meal (41% crude protein)	7.0	6.7	6.5	4.3	1.6
Molasses	4.0	4.0	4.0	4.0	4.0
Calcium carbonate (carbotex)	2.0	1.8	1.6	1.6	1.2
Dicalcium phosphate	0.0	0.0	0.0	0.0	0.1
Trace mineral salt[3]	0.5	0.5	0.5	0.5	0.5
Vitamin A palmitate	——— At a level to provide 1,000 IU/lb of feed ———				
Vitamin D_2	——— At a level to provide 60 IU/lb of feed ———				
Aureomycin (chlortetracycline)[4]	——— At a level to provide 15 mg/lb of feed ———				

[1] San Angelo Elevator, Inc. was the source of sorghum grain used in all diets. Steam-flaked sorghum grain was processed by Veribest Cattle Feeders, Inc., Veribest, Texas; dry-rolled by Angelo Feed and Supply, San Angelo, Texas. John Bonner and James Barr, Newman Feed Mills, Inc., coordinated grain processing and diet formulation.

Dry matter content of whole and dry-rolled sorghum grain was 86.2% compared with 82.2% for steam-flaked grain. Therefore, the amount of steam-flaked sorghum grain was increased proportionately to give the same percentage of dry matter from sorghum grain in all diets. Calcium propionate (0.25%) was added to all diets to prevent mold formation and heating in the stored diets with steam-flaked grain.

[2] Hammermill ground.

[3] See footnote 2, Table 2 (PR-3291).

[4] See footnote 4, Table 2 (PR-3291).

provided free choice, and unshrunk live weights were obtained initially and at 2-week intervals. Upon completion of a 49-day feeding period, the lambs were slaughtered in a commercial packing plant. The following day, visual evaluation of the chilled carcasses was made by a representative of the Texas Agricultural Experiment Station Meats Investigation Section.

Results and Discussion

Because different levels of roughage were employed, the final live weights of all lambs were adjusted to an equivalent dressing percent (51 percent), and this adjusted final live weight was used to calculate live weight gains (Table 3). Grain processing method significantly affected adjusted live weight gain ($P<.05$) and feed intake ($P<.01$). Performance was better for dry-rolled than for whole or steam-flaked sorghum grain. However, the response to grain processing method was not consistent across all levels of roughage as there were significant interactions between processing methods and roughage levels in the diet for adjusted live weight gain ($P<.01$), feed intake ($P<.05$) and pounds of feed required per pound of adjusted live weight gain ($P<.01$) (Table 4). With the all-concentrate (0 percent roughage) diet, live weight gain, feed intake and feed conversion were best with dry-rolled sorghum grain; at 10 percent roughage, whole grain appeared to give better performance; at 20 percent roughage, dry rolled was considerably superior to whole grain (Table 5).

Averaged across all treatments, alfalfa hay significantly improved live weight gain ($P<.01$) and feed conversion ($P<.01$) over peanut hulls (Tables 3 and 4). However, this difference was considerably greater at the 20-percent roughage level, possibly explaining the significant roughage source times roughage level interaction ($P<.01$) (Table 4).

Adjusted live weight gains were decreased with 20 percent roughage but not significantly. However, feed intake increased with increasing roughage in the diet ($P<.10$) as did feed required per pound of gain ($P<.01$).

Lamb performance for the various treament combinations (Table 5) indicates steam-flaked sorghum grain would be a poor choice for use in an all-concentrate diet and 20 percent peanut hulls would be undesirable in combination with whole sorghum grain. Dry-rolled sorghum grain gave more consistent performance across all levels of roughage. With the exception of dressing percent, none of the carcass data were significantly different.

Acknowledgments

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TABLE 3. DRYLOT PERFORMANCE AND CARCASS INFORMATION [1]

	Processing method			Roughage source		Roughage level, %		
Criterion	Whole	Dry-rolled	Steam-flaked	Alfalfa	Peanut hulls	0	10	20
Feeding period, days	49	49	49	49	49	49	49	49
No. lambs	48	48	48	72	72	48	48	48
Initial live weight, lb.	77.2	77.1	76.9	76.4	77.8	77.6	76.6	77.0
Live weight gain, adjusted lb/day[2]	0.406	0.453	0.383	0.442	0.386	0.430	0.430	0.383
Feed intake, lb./day	2.6	2.8	2.5	2.6	2.6	2.5	2.6	2.7
Feed conversion, lb. feed/lb. adj. gain	6.7	6.2	6.6	5.9	7.1	6.0	6.2	7.4
Dressing percent[3]	51.1	51.8	51.8	52.0	51.1	52.0	51.0	51.4
Warm carcass weight, lb.	49.6	50.6	48.8	50.0	49.4	50.3	49.8	48.9
USDA final grade[4]	12.5	12.8	12.4	12.7	12.4	12.6	12.5	12.6
Fat thickness, *I dorsi*, inches	0.20	0.22	0.21	0.22	0.21	0.21	0.21	0.22
Kidney and pelvic fat, estimated %	3.6	3.7	3.5	3.7	3.5	3.9	3.5	3.4
USDA yield grade[5]	3.3	3.4	3.3	3.4	3.3	3.4	3.2	3.3
Boneless consumer cuts, estimated %[6]	45.0	44.7	44.9	44.8	44.8	44.7	45.0	44.8

[1] Value for each treatment factor represents average across all other main treatments.

[2] Final live weight adjusted to an equivalent dressing percent (51%) was used to calculate live weight gain.

[3] See footnote 1, Table 5 (PR-3291).

[4] See footnote 2, Table 5 (PR-3291).

[5] See footnote 3, Table 5 (PR-3291).

[6] See footnote 4, Table 5 (PR-3291).

TABLE 4. PRELIMINARY STATISTICAL SUMMARY SHOWING PROBABILITY OF A SIGNIFICANT DIFFERENCE FOR TREATMENTS AND THEIR INTERACTIONS[1]

Source of variation	Criterion			
	Adjusted live weight gain	Feed intake	Feed/ adjusted gain	Dressing %
Treatments				
Grain Processing Method	P<.05	P<.01	ns	ns
Roughage source	P<.01	ns	P<.01	P<.05
Roughage level	ns	P<.10	P<.01	ns
Interactions[1]				
Processing × roughage source	ns	ns	ns	ns
Processing × roughage level	P<.01	P<.05	P<.01	ns
Source × level	ns	ns	P<.01	ns
Processing × source × level	ns	ns	ns	ns

[1]ns; no significant difference

P<.10; A significant effect with probability less than 10 in 100 the observed difference occurred by chance.

P<.05; A significant effect with probability less than 5 in 100 the observed difference occurred by chance.

P<.01; A significant effect with probability less than 1 in 100 the observed difference occurred by chance.

[2] A significant interaction indicates response to treatments was not consistent across the treatment combinations included in the comparison.

Feed Mills, Inc., for coordinating the grain processing and diet formulation and E. Mattingly, manager, Armour and Company, Lamb Plant, San Angelo, for assistance in making arrangements to slaughter these experimental lambs.

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TABLE 5. LIVE WEIGHT GAIN, FEED INTAKE AND FEED CONVERSION

Processing method	Roughage source	Roughage level, %		
		0[1]	10[2]	20[2]
	Live weight gain, lb/day			
Whole	Alfalfa		.474	.383
	Peanut hulls	.438	.459	.248
Dry rolled	Alfalfa		.402	.473
	Peanut hulls	.513	.387	.429
Steam flaked	Alfalfa		.475	416
	Peanut hulls	.338	.382	.347
	Feed intake, lb./day			
Whole	Alfalfa		2.7	2.5
	Peanut hulls	2.6	2.7	2.6
Dry rolled	Alfalfa		2.6	2.7
	Peanut hulls	2.8	2.7	3.0
Steam flaked	Alfalfa		2.6	2.6
	Peanut hulls	2.1	2.4	3.0
	Feed conversion, lb.feed/lb. gain			
Whole	Alfalfa		5.6	6.6
	Peanut hulls	5.9	5.9	10.4
Dry rolled	Alfalfa		6.5	5.8
	Peanut hulls	5.6	7.1	7.0
Steam flaked	Alfalfa		5.4	6.2
	Peanut hulls	6.4	6.5	8.6

[1] Each value is the average response for 16 lambs.

[2] Each value is the average response for 8 lambs.

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PR-3290

Alkali Supplementation Of High Concentrate Lamb Diets

M. C. Calhoun, Maurice Shelton and W. W. Linderman

SUMMARY: Both calcium hydroxide and potassium bicarbonate have had beneficial effects in reducing acidosis occurring in ruminants fed high- or all-concentrate diets. Response to these compounds was

further defined. Increasing potassium bicarbonate from 0 to 3 percent of the diet increased live weight gains and decreased the amount of feed required per pound of gain only when 0.5 percent calcium hydroxide was added and only for the first 14 days of the trial. It was concluded that there is no advantage from prolonged alkali supplementation of high grain (≥10 percent roughage) diets based on dry-rolled sorghum grain after lambs completely adapt to such diets.

Introduction

The problem of acidosis in ruminants fed high- or all-concentrate diets is well recognized (Dunlop, 1961; Ryan, 1963; Wise *et al.*, 1968). Acute acidosis can be a cause of death when cattle or sheep are first exposed to high grain diets, and subacute or chronic acidosis may be a contributing factor when performance is suboptimal throughout the feeding period (Koers, 1973).

Administration of alkali compounds has reduced problems with acute acidosis occurring when lambs were rapidly switched from roughage to a high grain diet (Calhoun and Shelton, 1969; Church, 1972). It is less clear whether continuous low level (1 to 3 percent) alkali supplementation of high- or all-concentrate diets is beneficial (Wise *et al.*, 1968). However, Shelton and Calhoun (1970) observed consistent improvements in rate of live weight gain and feed efficiency with the addition of 0.5 percent calcium hydroxide to high-concentrate lamb diets based on dry-rolled sorghum grain, and Calhoun and Shelton (1974) reported an improvement in live weight gain in seven of nine lamb feeding trials where potassium bicarbonate was added to high- or all-concentrate diets. Potassium bicarbonate supplementation improved feed efficiency in eight of the nine trials.

Comparison of the responses to either potassium bicarbonate or potassium chloride additions to a high-concentrate diet indicated that improvement in lamb performance was a result of bicarbonate and not potassium (Calhoun and Shelton, 1974). Potassium bicarbonate improved lamb performance only during the first 28 days of the feeding period. This occurred even though the lambs were changed stepwise over a 14-day period to the high-concentrate diet before the start of the experiment.

In previous trials with calcium hydroxide and potassium bicarbonate, lambs were switched directly onto the high-concentrate diets; thus, the beneficial response obtained may have been due to a reduction in stress, initially in the feeding period, with no advantage after the lambs became adapted to the 10-percent roughage, high-grain diet (Shelton and Calhoun, 1970; Calhoun and Shelton, 1974).

Since both calcium hydroxide and potassium bicarbonate have shown a beneficial effect when added to high-concentrate lamb diets, this experiment was conducted to further define the response to these compounds and examine the possibility that the effect might be additive.

Experimental Procedure

Typical Texas feeder lambs of mixed sex (ewe and wether Rambouillet X black-faced crossbred lambs) were maintained on a high-roughage diet until they were sheared, drenched[1] and weighed and allotted at random to pens (24 pens with 8 lambs per pen).

They were then switched to a 40-percent cottonseed hull diet and adapted stepwise over a 14-day period to a 10-percent cottonseed hull, high concentrate diet (Table 1). During this period all lambs were implanted with 12 milligrams (mg) of zearalanol;[2] and

[1] *l*-tetramisole hydrochloride: American Cyanamid Co., Princeton, New Jersey; Tramisol(R); two-thirds ounce of a water solution containing 0.41 gram/oz was administered orally.
[2] Zearalanol, Commercial Solvents Corp., Ralgro(R), 12 mg per implant.

TABLE 1. PERCENT INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS

	Adaptation diets		Comparison period diets			
	40%	10%	% $KHCO_3$			
Ingredient	roughage	roughage	0.0	1.0	2.0	3.0
Sorghum grain, dry rolled	45.0	79.5	83.5	82.25	81.0	79.75
Cottonseed hulls	40.0	10.0	10.0	10.0	10.0	10.0
Cottonseed meal, 41% crude protein	5.0			0.25	0.50	0.75
Dehydrated alfalfa meal, 17% crude protein	3.0	3.0				
Urea, 281% crude protein equivalent	1.0	1.0	1.0	1.0	1.0	1.0
Carbotex, calcium carbonate	1.0	1.5	1.5	1.5	1.5	1.5
Trace mineralized salt[1]	1.0	1.0	1.0	1.0	1.0	1.0
Molasses	4.0	4.0	3.0	3.0	3.0	3.0
Potassium bicarbonate[2]			0.0	1.0	2.0	3.0
Vitamin A palmitate	——— Added at a level to provide 1,000 IU/lb. of diet ———					
Aureomycin (chlortetracycline)[3]	——— Added at a level to provide 15 mg/lb. of diet ———					

[1] See footnote 2, Table 2 (Calhoun and Shelton, 1974).
[2] See footnote 3, Table 3 (Calhoun and Shelton, 1974).
[3] See footnote 4, Table 2 (Calhoun and Shelton, 1974).

because of a high incidence of soremouth, all lambs without apparent soremouth lesions were vaccinated.[3]

Two levels of calcium hydroxide (0 and 0.5 percent) and four levels of potassium bicarbonate (0, 1, 2 and 3 percent) were used.

Ingredient composition of the experimental diets is given in Table 1. An additional set of four diets (not shown) contained 0.5 percent calcium hydroxide in combination with the four levels of potassium bicarbonate. Calcium hydroxide replaced 0.5 percent sorghum grain in these diets.

After 42 days, 72 lambs were slaughtered in the Texas Agricultural Experiment Station Meat Laboratory at College Station so that rumen pH could be measured. The remainder were slaughtered at a commercial lamb packing plant, and a representative of the Meats Investigation Section of the Animal Science Department, Texas A&M University, assisted with evaluation of the lamb carcasses after they had chilled in the cooler overnight (approximately 16 hours).

Results and Discussion

The nutrient composition of the diets is shown in Table 2. The diets without added potassium bicarbonate averaged 0.54 percent potassium. Each 1-percent increase in potassium bicarbonate increased the potassium concentration approximately 0.39 percent. Previous research indicates that the lowest level would be adequate to meet the dietary potassium requirements of lambs used in this study (Calhoun and Shelton, 1974), whereas the highest level, 1.70 percent, might have a slight adverse effect on lamb performance (Telle *et al.*, 1964; Jackson, Kromann and Ray, 1971). Thus, any positive response obtained from adding potassium bicarbonate to the diets used in this study would appear to be unrelated to increasing potassium concentrations.

Because high concentrate diets based on sorghum grain are deficient in calcium, 1.5 percent calcium carbonate was added to all diets to eliminate the possibility of a problem with urinary calculi (water belly) which is frequently encountered when supplemental calcium is not added to such diets. No cases of urinary calculi were observed. Calcium carbonate is alkaline in solution, neutralizes acid, exerts a buffering effect and would be a source of bicarbonate (HCO_3) in the rumen. Therefore, calcium carbonate was added at the same level to all diets. The addition of 0.5 percent calcium hydroxide to one-half of the diets added approximately 0.20 percent calcium and increased the calcium to phosphorus ratio; however, this was not expected to influence the results obtained.

A summary of the cumulative dry lot performance data for 14, 28 and 42 days is presented in Table 3. When either potassium bicarbonate or calcium hydroxide alone was added to the diet, there was no improvement in lamb performance for any of the time periods. However, increasing the percentage of potassium bicarbonate in the diet increased live weight gains and decreased the feed requirements per pound of gain when 0.5 percent calcium hydroxide was also present. This effect was evident at 14 and 28 but not at 42 days.

Since it appeared that a response might have occurred only initially, the response was separated out by periods, that is, 1-14, 15-28 and 29-42.

A significant response was obtained only for the 1-14 day period and and only with 0.5 percent calcium hydroxide in the diet.

[3] Soremouth vaccine, live scab virus, obtained from the Texas Agricultural Experiment Station, Sonora.

TABLE 2. NUTRIENT COMPOSITION OF DIETS (AS-FED BASIS)[1]

	0% calcium hydroxide				0.5% calcium hydroxide			
	Potassium bicarbonate, %				Potassium bicarbonate, %			
Nutrient	0	1	2	3	0	1	2	3
Dry matter, %	88.8 ±1.6[2]	88.8 ±0.8	88.6 ±0.8	88.8 ±1.1	89.0 ±1.2	88.8 ±1.3	88.7 ± .9	88.4 ±1.6
Crude protein, %	10.3 ±0.3	11.0 ±0.3	10.6 ±0.6	10.8 ±0.9	10.9 ±0.5	11.0 ±0.2	10.7 ±0.1	10.9 ±0.5
Digestible protein, %	*7.6*	*8.2*	*7.9*	*8.0*	*8.1*	*8.2*	*8.0*	*8.1*
Digestible energy, Mcal/lb.	*1.52*	*1.51*	*1.49*	*1.47*	*1.52*	*1.50*	*1.48*	*1.47*
Protein: energy, g DP/Mcal DE	*22.7*	*24.6*	*24.0*	*24.7*	*24.2*	*24.8*	*24.5*	*25.0*
Ash, %	4.0 ±0.3	4.7 ±0.2	5.4 ±0.3	5.7 ±1.0	4.2 ±0.3	4.9 ±0.6	5.2 ±1.0	6.6 ±0.2
Calcium, %	0.76±0.09	0.69±0.06	0.68±0.06	0.69±0.05	0.92±0.08	0.86±0.02	0.89±0.02	0.95±0.03
Phosphorus, %	0.24±0.03	0.22±0.03	0.22±0.02	0.23±0.03	0.21±0.02	0.22±0.02	0.22±0.02	0.22±0.02
Potassium, %	0.56±0.05	0.84±0.01	1.31±0.05	1.70±0.16	0.51±0.02	0.87±0.08	1.30±0.01	1.69±0.12
Calcium: phosphorus	*3.2:1*	*3.1:1*	*3.1:1*	*3.0:1*	*4.4:1*	*3.9:1*	*4.0:1*	*4.3:1*

[1] Dry matter, crude protein, ash, calcium, phosphorus and potassium were analyzed by methods outlined in Official Methods of Analysis of the Association of Official Analytical Chemists. 11th ed., Wash. D.C., 1970. Values in italics were calculated as follows: (1) Digestible protein from crude protein by using the factor 0.743; (2) Digestible energy from values reported in Atlas of Nutritional Data on United States and Canadian Feeds, National Academy of Sciences, Wash., D.C., 1971.

[2] Average value ± standard deviation.

The alkali supplements did not appear to alter rumen pH measurements made on samples of rumen fluid obtained from the three lambs in each pen that were slaughtered at College Station (Table 3), nor were any of the carcass measurements significantly influenced by the alkali treatments (Table 4).

TABLE 3. EFFECT OF POTASSIUM BICARBONATE AND CALCIUM HYDROXIDE SUPPLEMENTATION ON PERFORMANCE OF LAMBS FED A HIGH CONCENTRATE DIET

	0% calcium hydroxide				0.5% calcium hydroxide			
	Potassium bicarbonate, %				Potassium bicarbonate, %			
Criterion	0	1	2	3	0	1	2	3
14-day summary								
Lambs, number	24	24	24	24	24	24	24	24
Initial live weight, lb.	72.9	72.8	68.9	70.4	70.2	71.1	70.2	69.3
Live weight gain, lb./day	.461	.415	.408	.473	.417	.473	.557	.594
Feed intake, lb./day	2.22	2.59	2.24	2.66	2.43	2.89	2.54	2.74
Feed conversion, lb. feed/lb. gain	5.5	6.3	6.4	5.8	6.2	5.6	4.6	4.7
28-day summary								
Live weight gain, lb./day	.446	.461	.436	.488	.426	.547	.478	.560
Feed intake, lb./day	2.69	2.81	2.80	3.08	2.71	3.37	2.76	3.03
Feed conversion, lb. feed/lb. gain	6.1	6.1	6.4	6.4	6.4	6.2	5.8	5.4
42-day summary								
Live weight gain, lb./day	.427	.432	.406	.462	.399	.472	.420	.461
Feed intake, lb./day	2.91	2.99	2.91	3.14	2.84	3.51	2.89	3.13
Feed conversion, lb. feed/lb. gain	6.8	7.0	7.2	6.9	7.1	6.9	6.9	6.9
Rumen pH	5.8	5.6	5.7	5.7	5.8	5.7	5.5	5.7

TABLE 4. EFFECT OF POTASSIUM BICARBONATE AND CALCIUM HYDROXIDE SUPPLEMENTATION ON CARCASS CHARACTERISTICS OF LAMBS FED A HIGH CONCENTRATE DIET

	0% Calcium hydroxide				0.5% Calcium hydroxide			
	Potassium bicarbonate, %				Potassium bicarbonate, %			
Criterion	0	1	2	3	0	1	2	3
Warm carcass weight, lb.	47.3	47.2	44.6	45.5	43.9	46.4	46.0	48.9
Dressing percent[1]	52.0	52.1	51.8	51.1	50.8	52.5	52.2	51.9
USDA final grade[2]	11.1	11.1	10.9	10.9	10.6	11.1	10.6	11.0
Kidney and pelvic fat, estimated, %	3.6	3.7	4.0	3.6	3.5	4.0	3.8	4.1
Fat thickness over *l. dorsi*, inches	0.22	0.22	0.20	0.21	0.18	0.21	0.21	0.21
USDA yield grade[3]	3.4	3.4	3.4	3.4	3.2	3.5	3.4	3.5
Boneless retail cuts, estimated, %[4]	44.7	44.7	44.7	44.8	45.1	44.6	44.7	44.6
Loin eye area, sq. inches[5]	1.90	1.89	1.95	1.75	1.78	1.88	1.70	1.85
Fat color score[6]	2.8	2.9	2.9	3.0	2.8	3.0	3.1	2.9
Fat firmness score[7]	3.6	3.9	3.6	4.0	3.8	4.0	3.8	4.0

[1] Calculated using warm carcass weight and unshrunk final live weight.

[2] USDA (1960): Avg prime = 14; avg choice= 11; avg good = 8.

[3] USDA (1969).

[4] USDA estimated percent of boneless retail cuts = 47.7976 – 11.7953 (fat thickness over *l. dorsi*, in.) + 0.0916 (leg conformation score) – 0.4425 (est % kidney and pelvic fat).

[5] Measurement taken on three lambs/pen.

[6] Fat color score: 4 = white; 3 = creamy white; 2 = slightly yellow; 1 = yellow.

[7] Fat texture and firmness scores: 6 = firm and dry; 5 = moderately firm and moderately dry; 4 = slightly firm and slightly dry; 3 = slightly soft and slightly oily; 2 = moderately soft and moderately oily; 1 = soft and oily.

Initial response (1-14 days) to increasing levels of potassium bicarbonate when 0.5 percent calcium hydroxide was present in the diet and a lack of response after the first 14 days of the feeding period suggest the 14-day preliminary period was not adequate to allow lambs to completely adapt from a 40- to a 10-percent roughage diet. These results support the conclusion of a previous study (Calhoun and Shelton, 1974) that there is no advantage from prolonged alkali supplementation of high grain diets based on dry-rolled sorghum grain with a minimum amount of roughage ($\geq$10) after lambs completely adapt to such diets. Alkali supplements have been beneficial in situations where lambs are rapidly switched from roughage to a high concentrate diet (Calhoun and Shelton, 1969; Church, 1972). However, the more desirable approach would be to adapt lambs gradually to high grain diets.

Low levels of combinations of alkali compounds such as 0.5 percent calcium hydroxide along with 3 percent potassium bicarbonate might be of value in decreasing the stress of adaptation and improving performance during the first 2 to 4 weeks of a feeding period. Any of a number of alkali compounds probably would be effective for this application; however, levels of calcium hydroxide (readily available as commercial hydrated lime and relatively inexpensive) and magnesium oxide (Magox) above levels of 1.0 percent have been shown to affect palatability adversely; this is reflected in lowered feed intake and, consequently, in live weight gains (Calhoun and Shelton, 1972; Shelton and Calhoun, 1970). Excess amounts of a single element such as sodium or potassium have also been undesirable (Church, 1972). Thus, a mixture of alkali compounds appears to have the most merit. The addition of 1.5 percent calcium carbonate, 0.5 percent calcium hydroxide and 3 percent potassium bicarbonate improved lamb performance in this experiment. Other research (Church, 1972) indicates that sodium bicarbonate could replace potassium bicarbonate, and magnesium oxide could be used instead of calcium hydroxide.

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PR-3291

Potassium Source and Level In High Concentrate Lamb Diets

M. C. Calhoun and Maurice Shelton

SUMMARY: Potassium bicarbonate ($KHCO_3$) and potassium chloride (KCl) as sources of supplemental potassium in high concentrate diets were compared. Addition of potassium bicarbonate to a high concentrate (84.5 percent dry-rolled sorghum grain — 10 percent cottonseed hulls) control diet (0.46 percent potassium) to give levels of 0.82 and 1.22 percent potassium, significantly improved the drylot performance of lambs during the first 28 days of the trial. The addition of potassium in the form of potassium chloride did not significantly improve performance. There was no response to either source of potassium during the last 28 days of the 56-day feeding trial. These results indicate that 0.46 percent potassium (air dry basis) is adequate for growth of lambs fed a high-concentrate diet and continued bicarbonate supplementation is not beneficial after lambs become adapted to such a diet.

Introduction

Potassium is an essential mineral element in ruminant nutrition. It is the major intracellular cation, an important component of saliva and appears to aid in maintaining a desirable ionic medium for bacterial fermentation in the rumen (Ward, 1966). Because most roughages contain large amounts of potassium (>1.0 percent), potassium supplementation is not considered of importance in typical ruminant diets. An exception is the high-grain finishing rations presently used for cattle and lambs. Grain sorghum generally contains less than 0.4 percent potassium, with considerable variation in the actual amount present. Thus, limited roughage diets based on sorghum grain may need supplemental potassium.

Telle *et al.* (1964) used a combination of potassium bicarbonate ($KHCO_3$) and potassium carbonate (K_2CO_3) to provide from 0.1 to 0.62 percent potassium in a semipurified basal ration fed to lambs. Below 0.3 percent potassium, growth depression occurred almost immediately; above 0.3 percent there was a slight increase in live weight gain to the highest level studied, 0.62 percent. The potassium supplement increased the pH of the diet and provided supplemental HCO_3^-; thus, it is difficult to know whether the slight increase in performance above 0.3 percent was caused entirely by the potassium ion or by some improvement in the buffering capacity of the rumen.

Campbell and Roberts (1965) fed a semipurified ration supplemented with varying levels of K_2CO_3 to define the role of potassium in ovine nutrition. Levels studied ranged from 0.1 to 0.7 percent potassium. A level of 0.5 percent of the air dry ration was necessary to promote optimum feedlot performance. Rumen pH and microbial activity were not significantly changed by the addition of K_2CO_3.

In some cases bicarbonate (HCO_3^-)- and carbonate ($CO_3^=$)-containing compounds have improved the performance of ruminants fed either high concentrate or purified diets (Wise *et al.*, 1968). However, the results were not consistent. In a number of studies, Texas Agricultural Experiment Station staff members included $KHCO_3$ at low levels in high-concentrate lamb diets (Table 1). In seven of nine comparisons the potassium-supplemented lambs gained faster than the controls, and in eight of nine trials feed was used more efficiently for live weight gains. Since the potassium content of the control ration was measured only for comparisons 8 and 9 (0.66 percent K) and $KHCO_3$ was the only form fed, it is not certain whether the response was to additional potassium or to bicarbonate. To determine which, potassium bicarbonate and potassium chloride were compared in high concentrate diets.

TABLE 1. INFLUENCE OF SUPPLEMENTAL POTASSIUM IN THE RATION ON THE PERFORMANCE OF FEEDLOT LAMBS

	Control		Added potassium	
Criterion	Avg daily gain	Feed per lb. gain	Avg daily gain	Feed per lb. gain
Trial 1				
All concentrate	.357	5.49	.500	4.67
Trial 2				
80% concentrate	.471	5.49	.532	5.04
Trial 3				
All concentrate	.433	5.27	.420	5.17
Trial 4				
88% concentrate	.311	7.33	.299	7.75
Trial 5				
95% concentrate	.420	6.43	.485	5.98
Trial 6				
90% concentrate	.516	5.25	.520	4.96
Trial 7[1]				
90% concentrate	.495	6.45	.583	5.74
Trial 8[2]				
90% concentrate	.417	8.39	.511	7.45
Trial 9[3]				
90% concentrate	.417	8.39	.485	7.57
Summary	.426	6.50	.482	6.04

[1] In Trial 7 a mixed buffer consisting of potassium bicarbonate, magnesium oxide and calcium hydroxide was used, and the lambs were specifically challenged by exposing hungry lambs to a high-concentrate diet.

[2] The control groups for Trials 8 and 9 are the same.

[3] The experimental group in Trial 9 received 0.5% $Ca(OH)_2$ as well as 1% $KHCO_3$.

Experimental Procedure

Seventy-two Rambouillet and Rambouillet X black-faced ewe and wether feeder lambs initially were fed a 60 percent roughage (30 percent hammermill ground alfalfa hay and 30 percent cottonseed hull) diet and then adapted stepwise over a 14-day period to the 10 percent roughage control diet (Table 2).

The control diet contained 0.46 percent potassium; two others contained $KHCO_3$ and KCl added to the control diet at levels of 1 and 2 percent (Tables 2 and 3). It was originally intended to add sufficient $KHCO_3$ or KCl to give potassium levels in the complete diet of 0.8 and 1.2 percent. The diets with 1 and 2 percent $KHCO_3$ analyzed 0.82 and 1.22 percent potassium; but because of a feedmill error, the two KCl diets contained 1.04 and 1.52 percent potassium, respectively. The low level of potassium in the control diet was achieved by using a high-concentrate (84.5 percent dry-rolled sorghum grain) mixture with cottonseed hulls as the roughage, instead of alfalfa hay, and a minimum amount of molasses (2 percent). Feed and water were provided free choice. Live weights of lambs were measured at 28-day intervals during the 56-day trial. The lambs were slaughtered in the Texas Agricultural Experiment Station Meat Laboratory at

TABLE 2. PERCENT INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS

Ingredient	Control	$KHCO_3$ (1%)	$KHCO_3$ (2%)	KCl (1%)	KCl (2%)
Sorghum grain, dry rolled[1]	84.5	83.5	82.5	83.5	82.5
Cottonseed hulls	10.0	10.0	10.0	10.0	10.0
Molasses	2.0	2.0	2.0	2.0	2.0
Urea, 281% crude protein equivalent	1.0	1.0	1.0	1.0	1.0
Calcium carbonate, Carbotex	1.5	1.5	1.5	1.5	1.5
Trace mineral salt[2]	1.0	1.0	1.0	1.0	1.0
Potassium chloride, KCl				1.0	2.0
Potassium bicarbonate, $KHCO_3$[3]		1.0	2.0		
Vitamin A palmitate	Added at a level to provide 1,000 IU/lb. of diet				
Chlortetracycline[4]	Added at a level to provide 15 mg/lb. of diet				

[1] Dry rolled through a Davis Krimper-Kracker® mill.

[2] Guaranteed to contain between 91% and 95% salt, as NaCl, and not less than the following percentages of mineral elements: manganese as MnO, 0.30; zinc as ZnO, 0.25; iron as either Fe_2O_3 or $Fe_2(CO_3)_3$, 0.15; copper as CuO, 0.015; cobalt as $CoCO_3$, 0.01 and iodine as $Ca(IO_3)_2$, 0.01.

[3] Food grade potassium bicarbonate.

[4] Chlortetracycline: American Cyanamid Company. Aureofac 50, 50 g chlortetracycline per pound.

which time rumen samples were obtained, and the pH of the rumen contents was measured.

The response to increasing levels of potassium in the diet was determined by regression analysis (Steel and Torrie, 1960). The four pens of lambs on the basal diet (controls) were used in both regressions. Therefore, these regressions are not independent, and care must be exercised in the interpretation of these data.

TABLE 3. PERCENT NUTRIENT COMPOSITION OF EXPERIMENTAL DIETS[1]

Ingredient	Control	$KHCO_3$ (1%)	$KHCO_3$ (2%)	KCl (1%)	KCl (2%)
Nutrient composition (as-fed basis)					
Dry matter, %	89.2	88.6	89.5	88.9	90.0
Crude protein, %	11.7	12.2	11.9	11.6	11.8
Digestible protein, %	*9.3*	*9.2*	*9.1*	*9.2*	*9.2*
Digestible energy, Mcal/lb.	*1.53*	*1.51*	*1.50*	*1.51*	*1.50*
Protein: energy, g DP/Mcal DE	*27.6*	*27.7*	*27.5*	*27.7*	*27.7*
Calcium, %	0.68	0.65	0.81	0.72	0.75
Phosphorus, %	0.22	0.25	0.22	0.24	0.24
Calcium: phosphorus	3.1:1	2.6:1	3.7:1	3.0:1	3.1:1
Potassium, %	0.46	0.82	1.22	1.04	1.52

[1] Values in italics were calculated using average values for ingredient composition reported in the National Academy of Sciences, Atlas of Nutritional Data on United States and Canadian Feeds, Washington, D.C., 1971.

TABLE 4. EFFECT OF SOURCE AND LEVEL OF SUPPLEMENTAL POTASSIUM ON THE DRYLOT PERFORMANCE OF LAMBS

Criterion	Control	$KHCO_3$ 1%	$KHCO_3$ 2%	KCl 1%	KCl 2%
Lambs, number	24	12	12	12	12
Feeding period, days	28	28	28	28	28
Initial live weight, lb.	68.6	74.5	71.6	69.7	70.3
Live weight gain, lb./day	0.437	0.480	0.535	0.441	0.480
Feed consumption, lb./day	3.05	3.24	3.35	3.09	3.28
Efficiency, lb. feed/lb. gain	7.0	6.7	6.2	7.0	6.9
Feeding period, days	56	56	56	56	56
Live weight gain, lb./day	0.404	0.433	0.445	0.402	0.433
Feed consumption, lb./day	3.00	3.28	3.36	2.98	3.21
Efficiency, lb. feed/lb. gain	7.4	7.6	7.6	7.4	7.4
Rumen pH	5.06	5.04	5.08	5.13	5.20

Results and Discussion

$KHCO_3$ as the source of potassium during the first 28 days the lambs were on feed improved live weight gain ($P<.01$), feed intake ($P<.05$) and feed conversion ($P<.05$). (Table 4). In contrast, the response was not significant for any of these criteria when KCl was used to provide additional potassium.

During the second portion of the feeding period (29-56 days), only feed intake for the $KHCO_3^-$ supplemented lambs was linearly associated with increasing levels of potassium in the diet ($P<.05$). A comparison of the response to $KHCO_3$ for both periods is presented in Figure 1.

A slight positive response may have been obtained from potassium supplementation of the diet, though none of the differences for KCl were significant (Table 4). The significant improvement in all three drylot performance criteria (live weight gain, feed intake and feed conversion) when the source of potassium was $KHCO_3$, during the first 28 days, indicates an appreciable response associated with addition of HCO_3^- to the diet.

A lack of response to potassium supplementation from either source during the last 28 days of the experiment indicates that (1) 0.46 percent potassium is adequate for growth of lambs fed a high-concentrate diet, (2) continued HCO_3^- supplementation of a high-concentrate diet containing a minimum of 10 percent roughage (in this case cottonseed hulls) is not

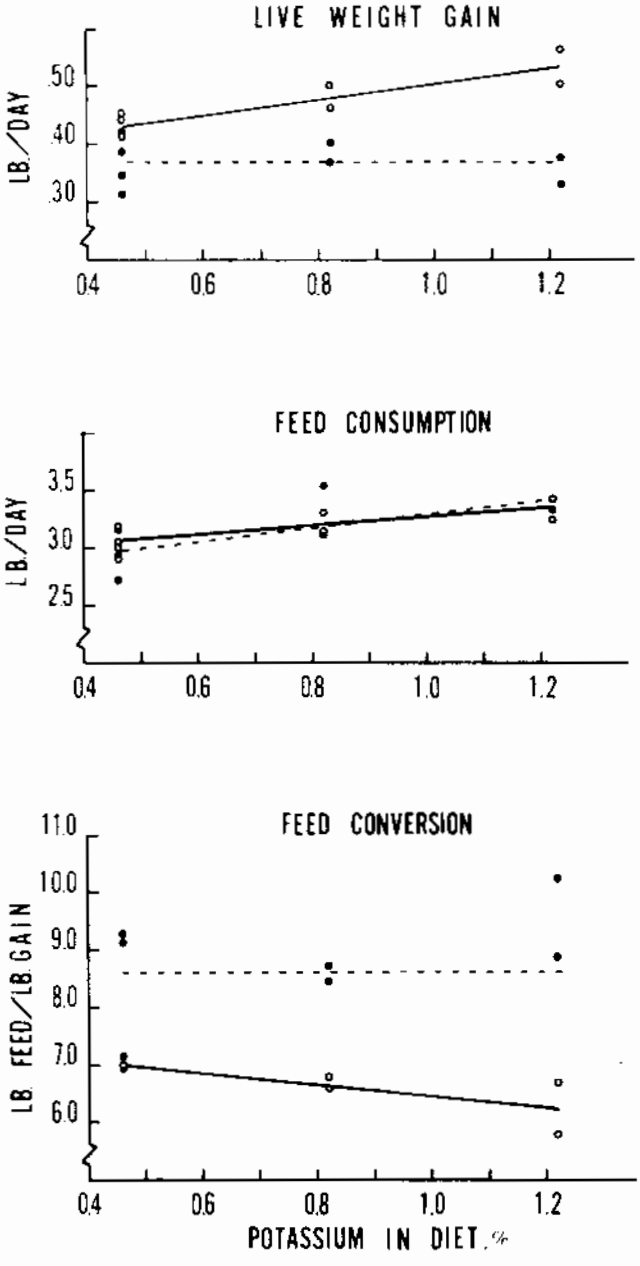

Figure 1. Association between live weight gain, feed consumption and feed conversion and potassium level in the diet when the source of potassium was $KHCO_3$ during the periods 1-28 and 29-56 days.

o———o 1-28 days

•– – – –• 29-56 days

beneficial after the lambs are well adapted to such a diet and (3) the 14-day adjustment period was not sufficient time for the lambs to adapt from an all-roughage to a high-concentrate diet.

Although values for potassium requirements of feeder lambs used in this study are consistent with those previously reported by others (Telle *et al.*, 1964; Campbell and Roberts, 1965), some of the response

TABLE 5. EFFECT OF SOURCE AND LEVEL OF SUPPLEMENTAL POTASSIUM ON THE CARCASS CHARACTERISTICS OF LAMBS.

		$KHCO_3$		KCl	
Criterion	Control	1%	2%	1%	2%
Warm carcass weight, lb.	49.9	54.9	54.4	51.1	51.8
Dressing percent[1]	53.5	55.0	55.2	54.1	54.5
U.S.D.A. final grade[2]	11.5	11.0	12	12	12
Kidney and pelvic fat, estimated %	4.8	4.9	5.2	4.6	5.1
Fat thickness over *l. dorsi*, inches	0.21	0.22	0.26	0.22	0.23
U.S.D.A. yield grade[3]	3.7	3.8	4.1	3.8	3.9
Boneless cuts, estimated %[4]	44.1	44.0	43.4	44.1	43.8
Loin eye area, sq. inches	1.82	1.96	1.97	1.95	1.88

[1] Calculated using warm carcass weight and unshrunk final live weight.

[2] USDA (1960): Avg. prime = 14; avg. choice = 11; avg. good = 8.

[3] USDA (1969).

[4] USDA estimated percent of boneless retail cuts = 47.7976 − 11.7953 (fat thickness over *l. dorsi*, in.) + 0.0916 (leg conformation score) − 0.4425 (est. % kidney and pelvic fat.).

they obtained when $KHCO_3$ and K_2CO_3 were used as sources of potassium in semipurified diets may have been attributable to the buffering effect of HCO_3^-.

Rumen pH, measured at time of slaughter, was not significantly different for the various treatments (Table 4). The lambs were loaded on a truck about 5 a.m. on the day of slaughter and transported 100 miles to the Meats Laboratory at College Station. Thus, the time off-feed prior to slaughter may have removed differences in pH which might be expected to result from addition of $KHCO_3$ to the diet. It is also possible that the levels used did not produce a large increase in rumen pH or that the lambs physiologically compensated for the long-term addition of this alkali buffer to their diet.

Carcass information obtained at slaughter showed no significant differences among treatments (Table 5).

Acknowledgments

The assistance of Gary Smith, Meats Investigation Section, Animal Science Department, in coordinating the slaughter of the lambs and collection of carcass data is appreciated.

Food grade potassium bicarbonate was supplied through the courtesy of B. A. Burns, Industrial Chemicals Division of Allied Chemical Corporation, Houston, Texas, and the chlortetracycline (Aureomycin(R)) through the courtesy of Donald Winfrey, American Cyanamid Company, San Angelo, Texas.

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PR-3292

Rumen Inoculation and Adaptation To High-Grain Diets

M. C. Calhoun, Maurice Shelton, C. S. Menzies, C. W. Livingston, Jr., and W. W. Linderman

SUMMARY: Inoculation with high-concentrate adapted rumen microorganisms was investigated for reduction of problems associated with switching lambs rapidly from a roughage to a high-grain diet. Strained rumen contents from lambs adapted to a 90-percent concentrate diet, obtained from lambs slaughtered in a commercial packing plant, were used as a 200-milliliter inoculum. In experiment 1 (21 days), rumen inoculation increased live weight gain 22.1 percent and decreased feed requirements per pound of gain 16.4 percent when lambs were placed immediately onto the pelleted high-concentrate (73.5 percent sorghum grain, 10 percent cottonseed hulls) diet. In experiment 2, both feed consumption and live weight gains were adversely affected by rumen fluid inoculation when compared with those of lambs administered an equivalent volume of deactivated (heated) rumen fluid or tap water. Conflicting results of the two experiments require further research for successful utilization of rumen contents of high-concentrate fed lambs.

Introduction

In lambs, the transition from typical roughage diets of range or pasture to high-grain finishing diets extensively used in feedlots requires a period of adaptation, during which roughage is gradually replaced with grain, to prevent problems with overeating and lactic acidosis (Hungate, 1966; Dirksen, 1970; Dunlop, 1961). Adaptation to high grain diets appears to involve changes in the microbial population in the rumen rather than in tissue metabolism of the host animal; beneficial results from inoculation during this period by using rumen fluid from animals already adapted to similar high grain diets have been reported (Hungate, 1966; Durham, Lopez and Martin, 1967; Allison, Bucklin and Dougherty, 1964; Huber, 1973).

The approximately 1,200,000 tons of rumen residue produced in the United States each year from commercial slaughter operations presents disposal problems to the meat packing industry (Begin and Fox, 1971). A large percentage is from cattle and sheep finished in feedlots on high-concentrate diets. At the same time, roughage materials used in adaptation rations are increasingly difficult to obtain in sufficient quantity and at a reasonable cost — the commercial utilization of rumen residue as a source of high concentrate adapted rumen microorganisms might have considerable merit. This would be expected to reduce the time required for adaptation, thus, the amount of roughage necessary, and to decrease the possibility of acidosis and associated problems during the transition from a roughage to a high-grain diet.

Two experiments were conducted to evaluate the practicality of obtaining rumen contents from lambs adapted to a high-concentrate diet and slaughtered in a commercial packing plant, as a source of inoculum for incoming lambs starting the transition from roughage to the same high-concentrate diet.

Experimental Procedure

In the first experiment, four lots with 25 lambs each were randomly assigned to the following experimental treatments: (1) roughage control; 40-percent cottonseed hull starter diet; lambs switched after 8 days to the high-concentrate finisher diet; (2) high concentrate control, lambs placed immediately on the high concentrate finisher diet; (3) high-concentrate diet plus rumen fluid, lambs started the same as for (2) except that each lamb was administered 200 milliliters of strained rumen fluid from lambs adapted to the high concentrate diet just before being started on feed; (4) high concentrate plus buffers, lambs started the same as for (2) except the diet contained 0.5 percent each of calcium hydroxide (hydrated lime) and magnesium oxide. All diets were fed free choice (Table 1), and water was available. The lambs were weighed initially and upon completion of a 21-day adaptation period.

Rumen fluid was obtained from lambs adapted to the high concentrate finisher diet at time of slaughter in a commercial lamb packing plant. The rumens were tied to prevent leakage, immediately placed in an insulated container and transported to the San Angelo research center. Rumen contents, strained through cheesecloth to remove particulate matter, were administered using a stomach tube and pump.

TABLE 1. INGREDIENT AND CALCULATED NUTRIENT COMPOSITION OF EXPERIMENTAL DIETS[1] [2]

Ingredient	Experiment 1			Experiment 2
	Starter diet	Finisher diet	Finisher and buffers	High concentrate diet
Sorghum grain, ground	38.0	73.5	72.5	74.0
Cottonseed hulls	40.0	10.0	10.0	10.0
Alfalfa, dehydrated	3.0	3.0	3.0	3.0
Cottonseed meal, 41% protein	8.5	5.0	5.0	6.0
Urea, 281% crude protein equiv.	0.5	0.5	0.5	0.75
Molasses	6.0	4.0	4.0	4.0
Salt	0.5	0.5	0.5	1.0
Calcium carbonate, carbotex	1.0	1.0	1.0	1.25
Calcium hydroxide, hydrated lime			0.5	
Magnesium oxide, Magox			0.5	
Aureomycin, chlortetracycline	Added at a level to provide 15 mg per lb. of feed.			
Vitamin A palmitate	Added at a level to provide 1,000 IU per lb. of feed.			
Bentonite, pelleting aid	2.5	2.5	2.5	
Total digestible nutrients, %	*62.4*	*73.7*	*72.8*	*74.7*
Digestible energy, Mcal/lb.	*1.24*	*1.47*	*1.45*	*1.49*
Crude protein, %	*11.3*	*12.6*	*12.4*	*13.7*
Digestible protein, %	*7.8*	*9.4*	*9.3*	*10.3*
g Digestible protein/Mcal digestible energy	*28.0:1*	*29.2:1*	*29.2:1*	*31.5:1*
Calcium, %	*0.58*	*0.52*	*0.72*	*0.63*
Phosphorus, %	*0.26*	*0.29*	*0.29*	*0.31*
Potassium, %	*0.77*	*0.57*	*0.56*	*0.58*
Calciumiphosphorus ratio	*2.2:1*	*1.8:1*	*2.5:1*	*2.0:1*

[1] All diets were prepared as ¼" pellets; 2.5 percent bentonite was added to all diets used in experiment 1.

[2] Nutrient composition was calculated using average values for ingredient composition reported in the National Academy of Sciences Atlas of Nutritional Data on United States and Canadian Feeds. Washington, D.C. 1971.

In experiment 2, the treatments were (1) high concentrate control, lambs switched immediately from roughage to the pelleted high concentrate diet (Table 1) after receiving 200 milliliters of water by stomach tube, (2) same as for (1) except 200 milliliters of rumen fluid deactivated by boiling given to each lamb at the onset of the experiment, (3) same as for (1) except 200 milliliters of viable rumen fluid inoculum administered to each lamb at the start. Four pens of five lambs each were assigned at random to each of the three treatments, making 20 lambs per treatment.

Feed and water were provided free choice, feed consumption was recorded daily and live weights of lambs were measured initially and upon completion of the 14-day period.

Results and Discussion

In experiment 1 (Table 2), one lamb in the high-concentrate control group lost 23 pounds in 21 days, apparently the only severe case of acidosis in this group. However, it is not unusual for an individual lamb to refuse to go back on feed after overeating initially or to refuse to adapt to a dry lot feeding situation without actually having been sick from overeating. Because the data for this lamb were excluded and observed live weight gains were not adjusted for differences in rumen fill, data in Table 2 slightly overestimate gains for the roughage control group.

With these limitations, rumen inoculation apparently improved live weight gains and feed efficiency during the 21-day adaptation period. The inclusion of buffers (0.5 percent each of calcium hydroxide and magnesium oxide) did not improve performance over the high concentrate control group.

In experiment 2, feed consumption during the first 24-hour period was significantly less ($P<.05$) for those lambs receiving the 200 milliliters viable rumen fluid inoculum (Table 3, Figure 1). However, decreased feed consumption during the second day indicated that all lambs had overeaten and were off-feed. Subsequently, feed intake gradually increased for all treatments, but the return was much slower for those lambs initially given the 200 milliliters viable rumen fluid inoculum.

Marked treatment differences were visible 48 hours after initiation of the experiment. Lambs receiving only 200 milliliters of water exhibited a high incidence of scouring; many appeared drawn and slightly dehydrated, and two were limping, indicative of possible laminitis. The lambs administered the 200 milliliters of inactivated (heated) rumen fluid scoured less

TABLE 2. ADAPTATION PERIOD PERFORMANCE OF LAMBS IN EXPERIMENT 1

Criterion	Experimental treatments				
	Roughage control	High Concentrate control	High concentrate + rumen fluid	High concentrate + buffers	SD
Days on experiment	21	21	21	21	
Lambs, number	25	24	25	25	
Initial live weight, lb.	67.6	70.0	70.2	7.2	
Live weight gain, lb./21 days	8.9	8.8	10.8	8.9	4.5
Average daily gain, lb./day	0.423	0.421	0.514	0.423	
Feed intake, lb./day	3.34	2.82	2.90	2.55	
Feed conversion, lb. feed/lb. gain	7.9	6.7	5.6	6.0	

TABLE 3. ADAPTATION PERIOD PERFORMANCE OF LAMBS IN EXPERIMENT 2[1]

Criterion	Control	Deactivated rumen fluid	Rumen fluid
Days on experiment	14	14	14
Lambs, number	20	14[2]	19[3]
Initial live weight, lb.	58.4	57.6	60.9
Average daily gain, lb./day	0.093	0.031	-0.338
Feed intake, lb./day	1.78	1.59	0.98

[1] Adaptation period experiment terminated on 14th day because of extremely poor condition of lambs given the rumen fluid inoculum.

[2] On the 8th day a pen of lambs (5) got out of the research barn during the night, and was attacked by stray dogs. As a result, two lambs died. This pen was removed from the experiment. One additional lamb died on the 12th day. Death was apparently due to an abomasal ulcer perforated through to the peritoneal cavity.

[3] One lamb died on the 8th day: tentative diagnosis, exterotoxemia.

than lambs given water; however, 4 of the 20 were bloated. In contrast, the viable rumen fluid group showed little evidence of scouring, only one lamb was bloated, and the general appearance was much better than that of the other two treatment groups. By the fifth day the situation was reversed. Even though little scouring was evident among lambs given viable rumen fluid, the majority appeared drawn, some severely drawn and depressed, whereas lambs on the other two treatments were eating more and appeared in better condition.

The performance of lambs receiving viable rumen fluid inoculation was considerably less than that of lambs administered an equivalent volume of deactivated (boiled) rumen fluid or tap water. These results are opposite from those in experiment 1 and are in general disagreement with other research (Allison *et al.*, 1974; Hungate, 1966; Durham *et al.*, 1967; Huber, 1973) in which an improvement in performance was associated with administration of rumen inoculum from adapted sheep or cattle. In the two experiments reported here, because the rumen fluid was from lambs adapted to similar high concentrate diets (Table 1), diet composition would not appear to be responsible. The difference in length of time off-feed prior to slaughter may have been a factor.

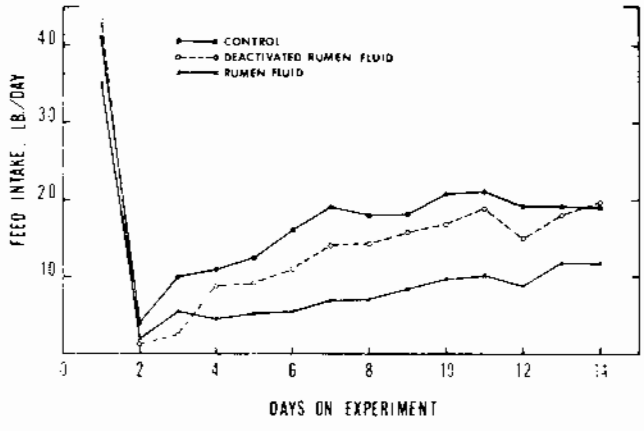

Figure 1. Average daily feed consumption of lambs during the 14-day adaptation period in experiment 2.

Allison *et al.* (1964) reported a similar case in which a sheep inoculated with ruminal fluid exhibited less tolerance to a cracked wheat diet than the uninoculated control. Since this was a single observation, animal difference was suggested as the reason. Although animal differences as well as microbial factors probably are involved in determining response to a changed diet, the uniformly adverse response of the 20 lambs for each treatment in experiment 2 indicates the rumen inoculum was the probable cause. This is substantiated by the fact that when the rumen inoculum was heated to inactivate the rumen microorganisms, live weight gains and feed consumption of that group approached those of the high concentrate control group.

Various research results indicate that rumen inoculum from high-concentrate adapted lambs could be valuable in reducing adaptation time and stress associated with switching lambs from roughage to high concentrate diets. However, the marked adverse effect in experiment 2 indicates incomplete understanding of procedures necessary to utilize such rumen contents successfully.

Acknowledgments

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PR-3293

Feeding Liquid Feed to Sheep

J. E. Huston, Maurice Shelton and Barron Rector

SUMMARY: Two liquid feed mixtures were evaluated as alternate sources of nutrients for sheep. Sheep readily consumed both regular and controlled release liquid supplements (32 percent crude protein) from lick-wheel feeders (0.39 and 0.36 pounds per head per day, respectively). The mature ewes fed these supplements had similar body weight changes and hay consumption as ewes fed 0.2 pounds of cottonseed meal per head per day. The data are not adequate to determine the relative value of the two liquid supplements.

Introduction

Recent developments in the sheep industry such as increased fertility, more frequent lambing and high intensity grazing place new and unstudied strains on the animal's system, especially as related to nutrition. The increased requirement for nutrients to support new intensive practices along with increased demands for grains and protein concentrates from competing industries indicate that much of the future supplies of feed for sheep will come from alternate sources. Liquid feeds (molasses-urea mixtures) have been fed with some success to cattle, but little information is available on the value of these mixtures for sheep. An experiment was conducted to determine the voluntary consumption of two such mixtures from conventional lick-wheel feeders by mature ewes fed hay free choice.

Experimental Procedure

Sixty mature, fine-wool ewes were randomly divided into four groups of fifteen ewes per group during a 35-day study. The four groups were assigned to the following treatments: (1) sorghum hay only, (2) sorghum hay plus 0.20 pound per head per day (lb./hd/day) cottonseed meal, (3) sorghum hay plus liquid supplement (LS) and (4) sorghum hay plus controlled-release liquid supplement (CRLS). The sorghum hay and liquid feeds were fed free choice and the cottonseed meal at 3-day intervals. Initial and final weights of ewes, consumption level of supplemental feeds and an estimate of hay consumption were recorded.

Results and Discussion

The results of the experiment (Table 1) were too variable, because of the short feeding period and/or the low number of animals, to make a sound conclusion on the relative value of the supplements. There was an indication that the basal diet (sorghum hay) was not adequate to maintain weight in the mature ewes and that all three supplements were sufficient to improve the overall diet. Once the ewes became accustomed to the mechanics of the lick-wheel (about 1 week), they readily consumed the viscous liquid even when nighttime temperatures dropped frequently under 32° F. Actual hay consumption was not determined because of large amounts of unaccountable waste. Figures reported in Table 1 are of relative value only.

A characteristic of most liquid feed formulations is that a large majority of the crude protein content is supplied by urea. Previous reports from Texas (Huston, 1973; Huston, Shelton and Breuer, 1969) have described efforts to reduce the toxicity and increase the value of urea by slowing its release in the rumen. These previous efforts cannot be applied to liquid

TABLE 1. LEVEL OF FEED CONSUMPTION AND WEIGHT CHANGES

Item	Treatment groups			
	1 Control	2 CSM	3 LS[1]	4 CRLS[1]
	lb.	lb.	lb.	lb.
Feed consumption (per day)				
Sorghum hay[2]	3.17	3.14	3.21	3.16
Supplement		0.19	0.39	0.36
Weights (35 days)				
Initial	105.0±4.1	107.7±3.4	108.2±2.9	108.2±2.6
Final	103.8±3.4	109.3±3.2	109.4±2.2	110.7±2.7
Change	-1.2±1.9	+1.6±2.3	+1.2±1.6	+2.5±1.6

[1] Liquid supplement (LS) and controlled-release liquid supplement (CRLS) produced and marketed by Cargill, Inc., as Cargill Liquid Supplement (CLS) and Cargill Liquid Supplement-Controlled Release (CLS-CR). Both are labelled to contain 32 percent crude protein.

[2] Indicates only the amount offered to the ewes. This includes both consumed and wasted hay.

feeds since controlled release urea requires a physical binding. The controlled-release liquid supplement (CRLS) fed in this experiment (produced and marketed by Cargill, Inc.) differs from regular liquid supplement (LS) in that it has been treated to produce a slow-release effect. These data are not adequate to determine whether a slow-release actually occurred and, if so, whether the effect was beneficial. The variations in response within each treatment suggest that the ewes did not uniformly consume the supplements or the hay. Studies with dry feeds indicate that slow-release urea can be more efficiently utilized than untreated urea. Thus, studies on the relative value of liquid feeds having different urea release rates should continue. The acceptability of the liquid feed by sheep and the small noted advantage of the controlled-release liquid supplement indicates promise for the use of liquid feeds for sheep and the need for more extensive and conclusive studies.

Acknowledgments

The liquid supplements and lick-wheel feeders essential to this experiment were supplied through the courtesy of Harlan Beucler, Nutrena Feed Division of Cargill, Inc., Minneapolis, Minnesota.

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PR-3294

Comparative Effects Of Ammonium Sulfate and Urea On Toxicity, Blood Ammonia And Blood Urea In Sheep

J. E. Huston and Barron Rector

SUMMARY: Because an increasing amount of ammonium sulfate is being used in ruminant ration formulations, the relative toxic effects of sudden doses of urea and ammonium sulfate in mature ewes and feeder lambs were studied. These nonprotein nitrogen sources were given separately and in combination at three dose levels. Two of three ewes in the high urea group died of acute ammonia toxicity. No toxic effect or elevated serum ammonia concentration could be attributed to any of the other treatments. Serum urea was significantly elevated in lambs dosed with urea in comparison with those dosed with ammonium sulfate at the high dose level. Lambs dosed with the combination of sources had intermediate serum urea levels. Collectively, these results indicate that ammonia from hydrolysis of urea was more rapidly absorbed and a greater hazard than ammonia from ammonium sulfate.

Introduction

In recent years an increasing amount of ammonium sulfate has been used in ruminant ration formulations. In formulations where supplemental nonprotein nitrogen (NPN) is allowed and supplemental sulfur is required, ammonium sulfate is often a "least cost" ingredient because of its relatively high nitrogen content (21 percent) and sulfur content (24 percent). Depending on NPN limitations and prices of alternative sources of NPN, the computer may select relatively high levels of ammonium sulfate in some formulations; this raises the question of possible toxic effects.

The authors know of no published data concerning relative toxicity of ammonium sulfate and urea, but it has been speculated that ammonium sulfate may be less toxic because of its acidic reaction in the rumen compared to the alkaline reaction of urea.

The relative effects of sudden doses of urea and ammonium sulfate were studied. Urea and ammonium sulfate were considered as separate and combined sources of nonprotein nitrogen in mature ewes and feedlot lambs.

Experimental Procedure

The relative effects of sudden doses of urea, ammonium sulfate and a 50:50 blend of the two were studied in a 3x3 factorial experiment. Each nitrogen source was given at three dose levels to single animals on 3 consecutive days. Identical trials were performed with ewes fed a maintenance ration and lambs fed a high energy ration (Table 1). Both groups had been fed their respective rations for at least 21 days prior to the experiment and were fasted for 12 hours prior to treatment. The three doses were administered with a commercial drench syringe and provided 3.1, 6.2 and 9.3 grams of nitrogen per 100 pounds of live weight.

The sheep were observed continuously for 4 hours after dosing. Blood samples were taken from

TABLE 1. RATIONS USED IN EXPERIMENTS TO COMPARE RELATIVE EFFECTS OF NITROGEN SOURCES IN SHEEP

	Ingredients	Percent of Total
Experiment 1	Sorghum hay[1]	100.00
Experiment 2	Peanut hulls	10.00
	Dehydrated alfalfa	3.00
	Milo meal	71.50
	Cottonseed meal	8.00
	Urea	1.00
	Caltex	1.50
	Molasses	4.00
	Salt	1.00
	Vitamin A (10,000 IU/g.)	
	Aureomycin or Terramycin (15 mg/lb.)	
		100.00

[1] First-cut sorghum hay.

TABLE 2. CHANGES IN BLOOD SERUM AMMONIA NITROGEN LEVELS

	Source of nitrogen								
	Urea			Ammonium sulfate			Combination		
Dose level (g./100 lb.)	3.1	6.2	9.3	3.1	6.2	9.3	3.1	6.2	9.3
Sampling time (hours)	Change from initial level (mg/100 ml)								
EXPERIMENT 1 — EWES									
0.5[1]	0.2	0.2	0.2	0.3	0.4	0.3	-0.1	0.2	0.5
2.0[2]	-0.1	0.4	1.5[4]	0.3	0.2	0.2	0.3	0.1	0.7
4.0[3]	0.1	-0.1	-0.2[4]	0.4	0.3	0.3	0.1	0.1	0.2
EXPERIMENT 2 — LAMBS									
0.5[1]	-.01[a]	-.04[a]	.36[a]	.04[a]	.40[a]	.38[a]	.10[a]	-.08[a]	.11[a]
2.0[2]	.05[abc]	-.17[bc]	.24[a]	-.05[abc]	.09[ab]	.18[a]	-.25[c]	.02[abc]	.06[abc]
4.0[3]	.08[a]	-.14[a]	-.003[a]	.003[a]	-.74[a]	-.10[a]	-.28[a]	-.10[a]	-.02[a]

[a,b,c] Values having uncommon superscripts are significantly different ($P<0.05$)

[1,2,3] An analysis of variance was performed on data at each sampling time. No range test is shown in experiment 1 because of missing data points.

[1] Source of nitrogen - ns
Level of dose - ns
Interaction - ns

[2] Source of nitrogen - ns
Level of dose - $P<0.025$
Interaction - ns

[3] Source of nitrogen - ns
Level of dose - ns
Interaction - ns

[4] Values determined by missing data technique.

TABLE 3. CHANGES IN BLOOD SERUM UREA NITROGEN LEVELS

	Source of Nitrogen								
	Urea			Ammonium sulfate			Combination		
Dose level (g./100 lb.)	3.1	6.2	9.3	3.1	6.2	9.3	3.1	6.2	9.3
Sampling time (hours)	Change from initial level (mg/100 ml)								
EXPERIMENT 1 — EWES									
0.5[1]	1.0	1.9	0.8	0.8	1.4	1.9	1.3	0.6	2.5
2.0[2]	2.9	4.7	2.2[4]	4.8	3.9	6.6	6.4	5.7	9.4
4.0[3]	5.4	5.0	3.4[4]	5.4	9.3	8.6	4.4	10.1	13.0
EXPERIMENT 2 — LAMBS									
0.5[1]	.04[c]	3.4[a]	2.8[ab]	0.2[c]	1.6[abc]	1.8[abc]	0.7[bc]	1.3[abc]	2.4[ab]
2.0[2]	3.7[cd]	7.6[ab]	9.4[a]	1.2[d]	7.1[abc]	6.9[abc]	3.8[cd]	5.6[bc]	8.2[ab]
4.0[3]	5.3[cd]	10.2[ab]	13.5[a]	4.1[cd]	7.9[bc]	7.0[bc]	0.9[d]	7.1[bc]	11.2[ab]

[a,b,c,d] Values having uncommon superscripts are significantly different ($P<0.05$).

[1,2,3] An analysis of variance was performed on data at each sampling time. No range test is shown in experiment 1 because of missing data points.

[1] Source of nitrogen - ns
Level of dose - $P<0.005$
Interaction - ns

[2] Source of nitrogen - ns
Level of dose - $P<0.001$
Interaction - ns

[3] Source of nitrogen - $P<0.025$
Level of dose - $P<0.001$
Interaction - ns

[4] Values determined by missing data technique.

the jugular vein prior to dosing and at 0.5, 2 and 4 hours after dosing. More frequent samples were taken from animals showing signs of ammonia toxicity.

Results and Discussion

Results are presented in Tables 2 and 3 as deviations from initial levels. Each listed value is an average of the three replicates except for the high dose level of urea in experiment 1. Two of these ewes died at the indicated times following dosing, showing symptoms of ammonia toxicity. The 2-hour and 4-hour numbers were filled in by use of a missing data technique; this should be considered in interpretation of results.

Generally, blood ammonia concentrations failed to indicate any effect of source of nitrogen or level of dose in either of the experiments. This is the expected result if the dose remains low enough that the resulting absorbed ammonia does not exceed the capacity of the liver to detoxify ammonia. In experiment 1, two ewes died from the high level dose of urea. (Elevated blood ammonia is not indicated in Table 2 since values for these two ewes were not available at the designated sampling times.) However, the rapid rise in circulating ammonia in these two ewes prior to death (Figure 1) illustrates that for these particular sheep the level of ammonia absorption was too high for total liver detoxification and, therefore, at a toxic level. No similar effect was present for ewes on ammonium sulfate and a combination of the two or for lambs on any of the nitrogen sources. This suggests that (1) absorption of ammonia arising from urea hydrolysis was more rapid than that from ammonium sulfate and (2) diet (probably rumen pH) had an effect on rate of absorption of ammonia.

Circulating blood urea is an indicator of ammonia absorption since portal vein ammonia is incorporated into urea in the liver and contributes to the circulating urea pool. (The data on blood urea for experiment 1 are incomplete because of the absences of any value for the two ewes that died.) Comparing the am-

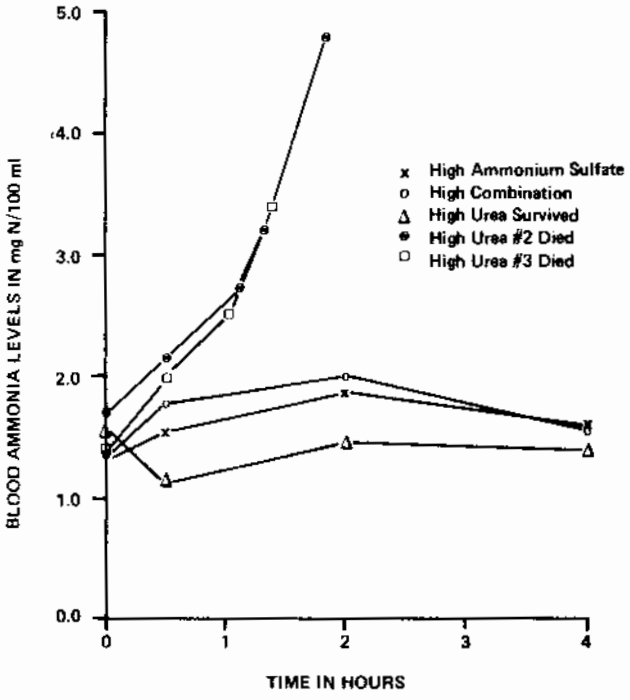

Figure 1. Comparison of high doses in response to the three treatments.

monium sulfate and combination sources, there was a non-significant elevated urea level for the ewes receiving the combination source of nitrogen (one-half of which was urea nitrogen). In experiment 2, the results are consistent with what would be expected if ammonia arising from urea hydrolysis was more rapidly absorbed than ammonia from ionization of ammonium sulfate. The 4-hour urea level in the lambs receiving the high urea dose was significantly higher than in those receiving ammonium sulfate. The level for the lambs receiving the high dose of combination source was intermediate. A similar pattern probably would have developed in Experiment 1 if the two missing values had been available.

Acknowledgments

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PR-3295

Ultrasonic Procedures And Visual Appraisal In Evaluating Carcass Merit In Sheep

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SUMMARY: Visual appraisal, body weight, rate of gain and ultrasonic estimates of fat thickness and ribeye area were compared as a means of predicting carcass merit of Rambouillet rams. In general, visual estimates had little value, but individual scorers probably can develop a competence which approaches that of the other measures employed. Body weight was significantly related to most expressions of carcass merit. However, the influence of body weight on carcass merit is largely an influence of the amount of fat, and this should be considered in selection only to the extent to which an individual animal differs from the norm for its weight range. Both ultrasonic fat thickness and ribeye area were significantly related to similar traits in the carcass and to other expressions of carcass merit. Ultrasonic fat thickness appears to be the most useful single value. Most methods were more accurate when applied to the lighter weight animals.

Introduction

Performance testing of rams has been conducted by the Texas Agricultural Experiment Station at Sonora for years. A selection index containing components to place selection pressure on rate of gain, fleece weight, staple length, open faces and smooth bodies has been used most of this time. This index does not place any emphasis on the important traits of fertility and carcass merit. Both traits present problems in measurement. Originally, conformation scores were assigned to all rams at the completion of each test. The definition of conformation was left to the interpretation of the individual scorer, and most were highly influenced by the then prevalent concept of desirable conformation being a deep, thick, blocky animal. These scores seemingly had no significant value in appraising carcass merit. For this reason no emphasis ever was placed on these scores in a selection index, and in recent years they have been dropped from data collection forms. The need to evaluate carcass desirability remains a high priority goal. Visual appraisal, body weight, rate of gain and ultrasonic estimates of fat thickness and ribeye area were compared as means of predicting carcass merit of rams.

Experimental Procedure

Beginning in 1971, all rams on test were evaluated ultrasonically for fat thickness and loin eye area. To evaluate the accuracy of this procedure, samples of these rams (89 Rambouillet rams) were slaughtered at the Texas Agricultural Experiment Station Meat Laboratory at College Station and fabricated into closely trimmed bone-in cuts. Similar data are available on 22 Suffolk rams and 52 ewe and wether lambs involved in the overall project. In 1972 a sample of 22 Rambouillet rams was visually evaluated before slaughter by eight people to estimate percent trimmed leg and loin, percent total trimmed consumer cuts, ribeye area and fat thickness over the ribeye. The scorers consisted of research and extension personnel and producers. Several had no previous experience in evaluating carcass characteristics of live sheep. Correlation coefficients were calculated to evaluate the accuracy of the various procedures.

TABLE 1. A COMPARISON OF VISUAL AND ULTRASONIC EVALUATIONS FOR 22 RAMBOUILLET RAMS[1]

	Trait			
Scorer	Percent trimmed leg and loin	Percent total consumer cuts	Fat thickness over rib	Ribeye area
1		-.113	-.022	.464*
2		-.089	.130	.573**
3	.168	.262	.108	.491*
4	-.247	-.131	.619**	.463*
5	.600**	-.151	.124	.549**
6	.522**	.186	.382	.792**
7	-.249	-.238	.046	.399
8	-.467	-.222	-.264	.265
Average of above coefficients	.020	-.054	.179	.492
Correlation of average of estimates with actual	.048	.010	.182	.636**
Body weight	-.548**	-.059	-.153	.582**
Ultrasonic fat thickness			.430*	
Ultrasonic ribeye area				.538**

[1] Values in table are correlation coefficients.

* Significant at 5-percent level.

** Significant at 1-percent level.

Results

The correlation coefficients between visual estimates and actual values for the 22 rams, along with the applicable ultrasonic values, are reported in Table 1. For percentage trimmed leg and loin and percentage total trimmed consumer cuts, there is almost no relationship between the assigned scores as a group and the actual values. Individual scorers may have had some success in scoring percentage leg and loin since two of the values are statistically significant. Scorers appeared to have limited success in scoring fat thickness as six of the eight resulted in positive correlations, and one value was highly significant. Ultrasonic estimates of fat thickness were significantly correlated with the actual values, but this relationship is smaller than might have been expected. These data suggest that as a general rule visual appraisal of various measures of carcass merit is largely without value but that individual scorers may develop a competence which approaches that of the ultrasonic methods.

Aside from visual evaluation, the only options currently available for appraising carcass merit in rams coming off test are performance data such as weight or rate of gain and ultrasonic values for fat thickness or loin eye area. The correlation of some of these values with various measures of carcass merit are shown in Table 2 for the larger sample of 89 rams. One-half of these carcasses were from rams completing the performance test, and the other one-half were slaughtered at younger ages and lighter weight to provide a range in size. All values are highly significant, indicating that all the values are related. As animals become larger the cuts become bigger, but when expressed as a percentage, the fat in the carcass increases and the percentage of trimmed cuts decreases. The two best predictors of value are body weight and ultrasonic fat thickness. The correlation values are reasonably high and, when compounded into predicative equations, are reasonably accurate. However, these results need further study before they are given great emphasis in selecting breeding stock.

TABLE 2. RELATIONSHIP OF VARIOUS LIVE ANIMAL TRAITS TO MEASURES OF CARCASS MERIT FOR RAMBOUILLET RAMS (n = 89)[1]

		Percent loin	Percent leg	Percent internal fat	Percent fat trim	Percent trimmed primals	Percent total consumer cuts	Fat depth, inches	Ribeye area, square inches
	Means & Range	12.69 (8.3–19.9)	20.75 (17.1–27.0)	3.95 (.80–7.80)	9.82 (2.5–18.1)	65.09 (56.3–78.3)	83.74 (73.3–92.7)	.190 (.02–.50)	2.71 (1.47–3.93)
Final weight, lb.	174.9 (100–241)	-.499	.621	.449	.554	-.560	-.537	.537	.714
Slaughter weight, lb.	155.6 (80–241)	-.650	.685	.470	.719	-.621	-.662	.532	.767
Avg daily gain, lb.	.532 (.331–.820)	-396	-.601	.492	.509	.579	-551	.593	.523
Ultrasonic fat thickness, inches	.191 (.04–.40)	-.378	-.574	.459	.551	-.665	-.561	.741	.412
Ultrasonic ribeye area, square inches	2.57 (1.16–4.00)	-.307	-.577	.366	.483	-.481	.464	.507	.723

[1]Unless otherwise indicated, values in table are correlation coefficients.

These correlation values are based on animals covering a wide range in body weight, whereas rams coming off test are of restricted weight range. When analyses are made within the restricted weight range, the correlation coefficients and their value in predictive equations are markedly reduced. The correlations are based on data broken into carcass weights below 60 pounds, 60-80 pounds, 80-100 pounds and above 100 pounds. Unfortunately, the correlations are higher for the lighter weight and are relatively low at the heavier weight ranges comparable to most of the rams coming off the test. One of the major components used in predicting carcass value has been body weight. At least the linear component of the contribution of body weight to carcass value is without merit or value for selection purposes, since it represents largely variation in age and feed level or management. To the extent that it is a factor in appraising carcass merit, it exercises a negative influence on such measures as percentage of primal or desired cuts, with the result that the larger animals are discriminated against. Only the extent to which an individual ram differs from the norm for his weight range (based on modifying information such as ultrasonic fat thickness) should estimates of carcass merit be used in selection. Of the measures studied in this report, ultrasonic fat thickness appears to be the most useful.

PR-3296

Relationship of Chronological Age To Skeletal and Muscle Maturity In Sheep Carcasses

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SUMMARY: Data from 238 lambs of known history were used to identify those skeletal or muscle maturity indicators which were most closely associated with progressive increases in chronological age at slaughter. A perfect system for assigning maturity scores to lamb carcasses would (1) segregate lambs according to meaningful differences in chronological age and (2) be equally applicable to carcasses of all sex classes. Of the scoring systems used to relate changes in muscle color, those for diaphragm and upper flank muscles were most closely related to differences in chronological age. Texas Agricultural Experiment Station (TAES) scores for diaphragm color were more closely associated with progressive changes in chronological age for both male and female carcasses than were U.S. Department of Agriculture (USDA) scores for the same trait. TAES scores for upper flank muscle color were most accurate of all scores for stratification of male carcasses into chronological age groups. Breakjoint and rib appearance scores were the most accurate indicators of changes in chronological age among measures of skeletal maturity. Breakjoint appearance scores achieved excellent stratification of carcasses according to age for males and females (TAES and USDA systems) and for the combined sex classes (TAES system). Rib appearance scores were most accurate for identifying age in male carcasses since such ratings achieved essentially perfect stratification. USDA scores for overall maturity were similar for male and female carcasses at chronological ages less than 280 days. Thereafter, female carcasses were assigned overall maturity scores indicative of a much faster rate of skeletal and muscle maturation than counterpart male carcasses of the same chronological ages. These data suggest that the use of breakjoint appearance as an indicator of progressive changes in chronological age is decidedly biased in the favor of male carcasses.

Introduction

Classification according to maturity is an integral part of U.S. Department of Agriculture (USDA) quality grading standards for ovine carcasses. Such assessments are used to separate lamb from yearling mutton or mutton carcasses and to identify relative youthfulness (by use of six categories, A-minus to B-plus) among carcasses commonly classed as lamb. Although it has been assumed that lambs undergo maturational changes in skeletal (ossification of bone) and muscle (darkening of lean) characteristics which are related to progressive increases in chronological age, little evidence has been presented to substantiate or refute this assumption. The earliest attempt to classify and grade ovine carcasses (Hall, 1910), the first official grade standards, which were established in 1931 (USDA, 1960), and some early research (Weber and Loeffel, 1932) assumed that increases in age or maturity were associated with decreases in palatability. Three concepts have formed the basis for maturity and grade identifications: that increases in age were negatively associated with palatability, that physiological maturity indicators sufficed for identifying progressive increases in age at slaughter and that physiological maturity (subjectively determined) was a more accurate index of palatability than was chronological age. The present study is the first in a series designed to test the authenticity of these theories and to determine the relationship between age and maturity assessments and the palatability of ovine meat.

Experimental Procedure

Lambs of known age and breeding from the Texas A&M University Agricultural Research Center at McGregor were fed at different energy levels to assure variability in level of fatness and associated quality characteristics. These lambs were slaughtered at different chronological ages to provide a range in carcass maturity.

On the second day following slaughter, an official representative of the Meat Grading Branch of the Consumer and Marketing Service evaluated each carcass according to the *Official United States Standards for*

Grades of Lamb, Yearling Mutton and Mutton Carcasses (USDA, 1960). Scores assigned to each carcass for certain skeletal and muscle maturity indicators are designated as USDA scores in the following discussions.

On the fifth day postslaughter, each carcass was subjectively scored for the same maturity indicators, and on the eighth day following slaughter, a loin and a leg from each carcass were scored for two additional traits. Two Texas Agricultural Experiment Station (TAES) personnel, acting independently, assigned these ratings (TAES scores) using a system ranging from 1 (least desirable) to 9 (most desirable), according to subjective visual appraisals or by visual comparisons with photographic standards. Carcasses having youthful lean colors, the least ossified bone structures, the least prominent rib cages (ribiness score) and the more desirably balanced hind and fore saddles (side view score) received the highest scores in both the USDA and TAES scoring systems.

After the traits were assigned numerical ratings, the independent scores were compared. If the scores were equal or differed by no more than one unit, the average value was recorded. When the scores differed by two or more numerical units, a compromise score was decided upon by reexamination of the carcass. Data were analyzed statistically.

Results and Discussion

USDA scores for diaphragm muscle color for carcasses of the combined sexes were not closely associated with progressive changes in chronological maturity (Table 1). Conversely, TAES scores more definitively segregated lambs according to chronological age at slaughter. Carcasses from lambs less than 100 days of age were significantly ($P<.05$) different from those in all other age groups.

TAES scores for diaphragm muscle color more definitively segregated male carcasses according to chronological age than did the USDA score but did not divide lambs less than 400 days of age into meaningful groupings. USDA diaphragm color scores for female carcasses failed to identify those carcasses from animals which were 520 to 580 days of age; but TAES scores segmented female carcasses into five strata differing significantly from each other (Table 1). Adequate stratification could be achieved by grouping all carcasses from animals less than 400 days of age into a common grouping. This would alleviate the problem in segmentation created by failure to identify lambs of 100 to 160 days and those which were 220 to 280 days of age.

USDA scores for upper flank color (Table 2) for combined sexes were not closely associated with progressive changes in chronological maturity, separating these carcasses into only two groups, with a division at 400 days of age. Similarly, TAES upper flank scores separated the carcasses from combined sexes into two groups, one below and the other above 340 days of age.

USDA scores failed to segregate male or female carcasses, and TAES scores failed to accurately segregate female carcasses according to chronological age at slaughter. However, TAES scores for upper flank muscle color segmented male carcasses into six strata which differed significantly from each other (Table 2). Adequate stratification could be achieved by this scoring system on male carcasses if those in the 400 to 460 day age group were included with those in the 340 to 520 day age group.

Both USDA and TAES scores for color of the intercostal and lower flank muscles (Tables 3 and 4) failed to accurately segregate carcasses into chronological age groupings.

TABLE 1. MEAN SCORES FOR DIAPHRAGM MUSCLE COLOR STRATIFIED ACCORDING TO AGE GROUPS

	USDA			TAES		
Age group (days)	Combined sexes	Males	Females	Combined sexes	Males	Females
Less than 100	8.64^{a}	8.64^{a}	8.67^{a}	8.75^{a}	8.68^{a}	9.00^{a}
100 to 160	8.61^{a}	8.50^{a}	8.80^{a}	7.68^{bc}	7.31^{d}	8.35^{ab}
160 to 220	8.60^{a}	8.50^{a}	8.78^{a}	8.04^{b}	7.94^{b}	8.22^{b}
220 to 280	8.60^{a}	8.42^{a}	8.88^{a}	7.88^{bc}	7.88^{b}	7.88^{bc}
280 to 340	8.35^{a}	8.46^{a}	8.20^{a}	7.35^{cd}	7.27^{d}	7.45^{c}
340 to 400	7.61^{ab}	7.57^{a}	7.67^{a}	7.42^{cd}	7.43^{c}	7.42^{c}
400 to 460	6.33^{bc}	6.50^{a}	6.42^{b}	6.63^{ef}	7.13^{e}	6.46^{e}
460 to 520	7.00^{abc}	7.43^{a}	6.25^{b}	6.98^{de}	7.00^{f}	6.94^{d}
520 to 580	7.19^{abc}	6.77^{a}	7.88^{a}	6.62^{ef}	6.50^{g}	6.81^{de}
580 to 640	6.23^{c}	6.20^{a}	6.10^{b}	6.17^{f}	6.20^{h}	6.00^{f}

^{abcdefgh}Means bearing different superscripts differ significantly ($P<.05$).

TABLE 2. MEAN SCORES FOR UPPER FLANK MUSCLE COLOR STRATIFIED ACCORDING TO AGE GROUPS

	USDA			TAES		
Age group (days)	Combined sexes	Males	Females	Combined sexes	Males	Females
Less than 100	9.00^{a}	9.00^{a}	9.00^{a}	8.93^{a}	8.91^{a}	9.00^{a}
100 to 160	8.86^{a}	8.83^{a}	8.90^{a}	8.21^{b}	7.94^{d}	8.70^{a}
160 to 220	8.44^{ab}	8.25^{a}	8.78^{a}	8.46^{ab}	8.38^{b}	8.61^{a}
220 to 280	8.55^{ab}	8.42^{a}	8.75^{a}	8.08^{b}	8.08^{c}	8.06^{ab}
280 to 340	8.43^{ab}	8.77^{a}	8.00^{a}	8.00^{b}	8.08^{c}	7.90^{abc}
340 to 400	7.94^{abc}	8.14^{a}	7.58^{a}	8.53^{c}	7.55^{e}	7.50^{bcd}
400 to 460	7.17^{bcd}	7.25^{a}	7.33^{a}	7.13^{cd}	7.08^{f}	7.21^{cde}
460 to 520	6.55^{d}	7.00^{a}	5.75^{b}	7.18^{cd}	7.50^{e}	6.63^{e}
520 to 580	6.90^{cd}	6.46^{a}	7.63^{a}	7.10^{cd}	6.92^{g}	7.38^{bcde}
580 to 440	5.81^{d}	5.80^{a}	5.60^{b}	6.92^{d}	6.83^{g}	6.90^{de}

^{abcdefg}Means bearing different superscripts differ significantly ($P<.05$).

TABLE 3. MEAN SCORES FOR INTERCOSTAL MUSCLE COLOR STRATIFIED ACCORDING TO AGE GROUPS

Age group (days)	USDA Combined sexes	USDA Males	USDA Females	TAES Combined sexes	TAES Males	TAES Females
Less than 100	8.86[a]	8.82[a]	9.00[a]	8.93[a]	8.95[a]	8.83[a]
100 to 160	8.79[a]	8.83[a]	8.70[a]	8.09[bc]	7.89[c]	8.45[a]
160 to 220	8.56[a]	8.44[a]	8.78[a]	8.34[b]	8.28[b]	8.44[a]
220 to 280	8.65[a]	8.75[a]	8.50[a]	8.28[b]	8.42[b]	8.06[ab]
280 to 340	7.96[ab]	8.31[a]	7.50[a]	7.72[cd]	7.73[cd]	7.70[bc]
340 to 400	7.36[abc]	7.52[a]	7.08[a]	7.59[d]	7.52[de]	7.71[bc]
400 to 460	6.00[d]	5.75[a]	6.08[a]	6.68[e]	7.21[fg]	7.00[d]
460 to 520	6.59[bcd]	6.78[a]	6.25[a]	7.36[de]	7.43[def]	7.25[cd]
520 to 580	6.86[bcd]	6.69[a]	7.13[a]	7.21[de]	7.31[fg]	7.06[d]
580 to 640	6.31[cd]	6.06[a]	6.50[a]	7.02[e]	7.06[g]	6.80[d]

[abcdefg]Means bearing different superscripts differ significantly (P<.05).

TABLE 5. MEAN SCORES FOR RIBEYE AND FORECUSHION COLOR STRATIFIED ACCORDING TO AGE GROUPS

Age group (days)	TAES Ribeye Combined sexes	TAES Ribeye Males	TAES Ribeye Females	TAES Forecushion Combined sexes	TAES Forecushion Males	TAES Forecushion Females
Less than 100	7.54[ab]	7.45[a]	7.83[a]	6.54[e]	6.36[f]	7.17[bcde]
100 to 160	7.04[bc]	6.71[bc]	7.67[a]	7.69[bc]	7.41[d]	8.22[a]
160 to 220	7.63[a]	7.56[a]	7.75[a]	8.17[a]	8.31[a]	7.88[ab]
220 to 280	7.35[ab]	7.46[a]	7.19[a]	7.83[ab]	8.00[b]	7.56[bc]
280 to 340	7.13[bc]	7.54[a]	6.60[b]	7.61[bc]	8.12[b]	6.95[cde]
340 to 400	7.09[bc]	7.33[a]	6.67[b]	7.55[bc]	7.71[c]	7.25[bcd]
400 to 460	6.25[d]	6.17[cd]	6.63[b]	7.06[de]	7.25[d]	7.00[cde]
460 to 520	6.70[c]	7.14[ab]	5.94[c]	7.30[cd]	7.68[c]	6.63[de]
520 to 580	5.62[e]	5.81[de]	5.31[d]	6.62[e]	6.62[e]	6.63[de]
580 to 640	5.54[e]	5.40[e]	6.15[c]	6.63[e]	6.63[e]	6.55[e]

[abcdef] Means bearing different superscripts differ significantly (P<.05).

TAES ribeye color scores for female carcasses were associated with progressive changes in chronological maturity (Table 5). Carcasses from animals less than 100 days to 280 days of age differed significantly (P<.05) in ribeye color from those which were 280 days and older at the time of slaughter and scores of those 280 to 460 days of age differed significantly (P<.05) from scores for those 460 days of age and older. Adequate stratification could be achieved by grouping all carcasses from animals older than 460 days of age into a common group. However, ribeye color scores failed to accurately segregate male carcasses or carcasses from the combined sexes, and scores for color of the forecushion muscle (Table 5) failed to accurately segregate carcasses into chronological age groups at slaughter.

USDA scores for breakjoint appearance separated carcasses from the combined sexes group into only two significantly (P<.05) different groups (lambs less than 280 days of age and those which were 400 to 640 days of age at slaughter) (Table 6). TAES scores for the combined sexes, however, more definitively segregated lambs according to chronological age at slaughter. Scores for breakjoint appearance segmented the carcasses into five strata which differed significantly from each other. Adequate stratification could be achieved by using this scoring system to evaluate the breakjoints of carcasses regardless of sex class. Both USDA and TAES scores for breakjoint appearance accurately segregated male carcasses into meaningful groupings with progressive changes in chronological maturity. There were significant (P<.05) differences between carcasses representative of every age group of animals. Minor inconsistencies in ranking occurred in both systems, but this would not detract from their usefulness in grade standard utilization.

USDA scores for breakjoint appearance segregated female carcasses into three strata which differed

TABLE 4. MEAN SCORES FOR LOWER FLANK MUSCLE COLOR STRATIFIED ACCORDING TO AGE GROUPS

Age group (days)	USDA Combined sexes	USDA Males	USDA Females	TAES Combined sexes	TAES Males	TAES Females
Less than 100	8.93[a]	8.91[a]	9.00[a]	8.86[a]	8.86[a]	8.83[a]
100 to 160	8.43[a]	8.33[a]	8.60[a]	7.65[c]	7.38[cd]	8.13[ab]
160 to 220	8.40[a]	8.19[a]	8.78[a]	8.25[b]	8.31[ab]	8.14[ab]
220 to 280	8.35[a]	8.42[a]	8.25[a]	8.05[bc]	8.08[b]	8.00[ab]
280 to 340	7.87[ab]	8.31[a]	7.30[a]	7.67[c]	7.77[bc]	7.55[bc]
340 to 400	7.06[bc]	7.19[a]	6.83[a]	7.21[d]	7.19[cd]	7.25[c]
400 to 460	6.25[cd]	6.08[a]	6.08[a]	6.40[e]	6.38[ef]	6.50[d]
460 to 520	5.95[cd]	6.21[a]	5.50[a]	6.66[e]	6.79[de]	6.44[d]
520 to 580	6.05[cd]	5.85[a]	6.38[a]	6.43[e]	6.08[f]	7.00[cd]
580 to 640	5.46[d]	5.00[a]	6.00[a]	6.52[e]	6.53[ef]	6.35[d]

[abcdef] Means bearing different superscripts differ significantly (P<.05).

TABLE 6. MEAN SCORES FOR BREAKJOINT APPEARANCE STRATIFIED ACCORDING TO AGE GROUPS

Age group (days)	USDA Combined sexes	USDA Males	USDA Females	TAES Combined sexes	TAES Males	TAES Females
Less than 100	8.57[a]	8.45[a]	9.00[a]	8.36[a]	8.32[a]	8.50[a]
100 to 160	8.25[a]	8.00[c]	8.70[a]	8.07[a]	8.06[b]	8.10[a]
160 to 220	8.20[a]	8.13[b]	8.33[a]	7.88[a]	7.59[c]	8.39[a]
220 to 280	7.79[ab]	7.73[d]	7.88[a]	7.34[b]	7.14[e]	7.63[b]
280 to 340	6.57[bc]	7.54[e]	5.30[b]	6.52[c]	7.00[f]	5.90[c]
340 to 400	6.39[c]	7.24[f]	4.92[b]	6.61[c]	7.26[d]	5.46[d]
400 to 460	4.96[d]	6.17[g]	3.92[bc]	5.19[d]	6.50[g]	4.29[e]
460 to 520	4.71[d]	5.71[i]	2.71[c]	4.76[d]	5.71[i]	2.86[f]
520 to 580	4.90[d]	5.92[h]	3.00[c]	4.88[d]	5.88[h]	3.00[f]
580 to 640	3.62[d]	4.60[j]	2.40[c]	3.40[e]	4.27[j]	2.25[g]

[abcdefghij] Means bearing different superscripts differ significantly (P<.05)

TABLE 7. MEAN SCORES FOR RIB APPEARANCE STRATIFIED ACCORDING TO AGE GROUPS

Age group (days)	USDA			TAES		
	Combined sexes	Males	Females	Combined sexes	Males	Females
Less than 100	8.29[a]	8.27[a]	8.33[ab]	8.18[a]	8.23[a]	8.00[a]
100 to 160	8.07[a]	8.00[c]	8.20[ab]	8.11[a]	8.19[b]	7.95[a]
160 to 220	8.16[a]	8.00[c]	8.44[a]	7.70[ab]	7.66[c]	7.78[a]
220 to 280	7.40[ab]	7.17[e]	7.75[ab]	7.35[bc]	7.29[d]	7.44[a]
280 to 340	7.22[ab]	7.46[d]	6.90[abc]	6.93[cd]	7.15[e]	6.65[b]
340 to 400	6.82[ab]	6.90[f]	6.67[bc]	6.74[d]	6.88[f]	6.50[b]
400 to 460	5.71[b]	6.17[g]	5.58[cd]	5.85[e]	6.00[g]	5.96[c]
460 to 520	5.95[b]	5.86[f]	6.13[bcd]	5.82[e]	5.61[h]	6.19[bc]
520 to 580	6.00[b]	6.00[h]	6.00[bcd]	5.36[e]	5.54[f]	5.06[d]
580 to 640	4.15[c]	3.93[i]	4.60[d]	4.31[f]	4.53[i]	4.00[d]

[abcdefghi] Means bearing different superscripts differ significantly (P<.05).

TABLE 8. MEAN SCORES FOR SIDE VIEW AND RIBINESS STRATIFIED ACCORDING TO AGE GROUPS

Age group (days)	TAES Side View			TAES Ribiness		
	Combined sexes	Males	Females	Combined sexes	Males	Females
Less than 100	5.8[ab]	5.5[a]	6.5[ab]	5.4[a]	5.4[a]	5.5[a]
100 to 160	6.2[a]	6.0[a]	6.8[a]	5.6[a]	5.6[a]	5.8[a]
160 to 220	5.4[b]	5.5[a]	5.3[c]	5.6[a]	5.4[a]	6.1[a]
220 to 280	5.4[b]	5.4[a]	5.3[c]	5.7[a]	5.4[a]	6.1[a]
280 to 340	5.3[b]	5.0[a]	5.8[bc]	5.5[a]	5.1[a]	5.9[a]
340 to 400	5.3[b]	5.0[a]	5.8[bc]	5.5[a]	5.5[a]	5.4[a]
400 to 460	5.3[b]	5.3[a]	5.6[c]	5.0[a]	5.0[a]	5.0[a]
460 to 520	5.3[b]	5.0[a]	5.8[bc]	5.3[a]	5.1[a]	5.6[a]
520 to 580	4.7[c]	4.7[a]	4.6[d]	4.8[a]	4.6[a]	5.1[a]
580 to 640	4.8[c]	5.1[a]	4.3[c]	5.5[a]	5.1[a]	6.2[a]

[abcd] Means bearing different superscripts differ significantly (P<.05).

significantly (P<.05) from each other (Table 6). TAES scores for breakjoint appearance identified and segregated female carcasses according to chronological age into seven strata which differed significantly from each other (Table 6).

USDA scores for rib appearance (Table 7) for combined sexes were not as closely associated with progressive changes in chronological maturity as were breakjoint appearance scores. TAES scores more definitively segregated lambs according to progressive changes in chronological maturity. Carcasses from lambs which were less than 100 to 160 days of age differed significantly (P<.05) in rib appearance from those which were 220 days of age and older at the time of slaughter. Carcasses in the age groups from 280 to 400 days had significantly (P<.05) lower rib appearance scores than any other age group except those 220-280 days of age. Carcasses in age group 7 through 9 (400 to 580 days) differed significantly (P<.05) from all other age groups in scores for rib appearance, and those in group 10 (580 to 640 days of age) differed significantly (P<.05) from carcasses of all other ages.

Both USDA and TAES scores for rib appearance accurately segregated male carcasses into meaningful groups with advancements in chronological maturity with significant (P<.05) differences between all age groups. USDA scores for female carcasses did not differentiate between carcasses from animals as old as 580 days of age, but TAES scores segmented female carcasses into three general strata which differed significantly (P<.05) from each other (Table 7). Adequate stratification could be achieved by grouping all carcasses from animals more than 520 days of age into one group. Rib appearance scores would be most useful for male carcasses since such ratings achieved essentially perfect stratification.

TAES scores for side view and ribiness (Table 8) were closely associated with progressive changes in chronological age. Of skeletal maturity indicators, breakjoint and rib appearance are most closely related to age at slaughter.

USDA overall maturity scores effectively separated the carcasses from the combined sexes into three groups — one group less than 280 days of age, one group 340 to 400 days of age and a third group 400 to 640 days of age at slaughter (Table 9). These strata contained lambs which were less than 9 months, 11 to 13 months and 13 to 22 months, respectively, of age at slaughter. Using USDA nomenclature, the most youthful group was identified as A-minus to typical-A, the middle strata as B-minus and the least youthful group as typical-B to yearling mutton-minus.

Overall maturity scores failed to accurately segregate male carcasses according to chronological age within the 160- to 460-day age range but did segregate carcasses into a young group (less than 100 days to 160 days of age) or an old group (460 to 640 days of age at slaughter). USDA overall maturity scores segregated

TABLE 9. MEAN SCORES FOR OVERALL MATURITY AND USDA MATURITY GROUPS STRATIFIED ACCORDING TO RANGES IN CHRONOLOGICAL AGE

Age group (days)	Combined sexes		Males		Females	
	Overall maturity score	USDA maturity group	Overall maturity score	USDA maturity group	Overall maturity score	USDA maturity group
Less than 100	9.00[a]	A–	9.00[a]	A–	9.00[a]	A–
100 to 160	8.46[a]	A°	8.33[a]	A°	8.70[a]	A°
160 to 220	8.40[a]	A°	8.25[ab]	A°	8.67[a]	A°
220 to 280	8.25[a]	A°	8.25[ab]	A°	8.25[a]	A°
280 to 340	7.43[ab]	A–	8.23[ab]	A°	6.40[b]	B–
340 to 400	6.01[b]	B–	7.38[abc]	A+	5.25[bc]	B°
400 to 460	5.25[c]	B°	6.42[abcd]	B–	4.42[cd]	B+
460 to 520	4.77[cd]	B+	6.00[bcd]	B–	2.63[e]	YM°
520 to 580	4.86[cd]	B+	5.62[cd]	B°	3.25[de]	YM–
580 to 640	3.69[d]	YM–	4.27[d]	B+	3.00[e]	YM–

[abcde] Means bearing different superscripts differ significantly (P<.05).

female carcasses into three strata which differed significantly ($P<.05$) from each other (Table 9). However, USDA nomenclature would have identified these groups as A-minus to typical-A, B-minus and yearling mutton-minus to typical-yearling mutton with the latter two at ages approximately 60 to 120 days earlier than counterpart males of the same chronological ages.

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Bacterial Decontaminating Agents For Lamb Carcasses

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SUMMARY: Three experiments involving 214 lamb carcasses determined the effects of elevated storage temperature, wrapping in polyvinyl choride (PVC) film and bacterial decontaminating agents on shrinkage losses, bacterial counts and palatability traits. Shrinkage losses for lambs wrapped in PVC film were substantially reduced, and the external fat surface was extremely attractive when compared to other treatment groups. Unfortunately, the use of PVC film also was associated with substantial increases in bacterial count. Storage of lamb carcasses at 16° C for 24 hours was associated with increased tenderness but also with increased bacterial growth. The use of dilute solutions of chlorine (0.02 percent) was associated with substantial reductions in bacterial count on lamb carcasses, yet had no appreciable effect on the flavor of subsequent lamb chops. Decontaminating agents were most effective in reducing bacterial growth when they were applied to carcasses immediately postmortem. Use of decontaminating agents after 7 days of storage effected a decimal reduction in bacterial counts. Combined use of PVC film and decontaminating agents immediately postmortem, in an attempt to simultaneously reduce shrinkage and microbial growth, did not produce consistent reduction in bacterial counts.

Introduction

Under ideal conditions, lamb carcasses entering the chill cooler should have little microbial contamination, but under normal conditions of slaughter and dressing this is extremely difficult to achieve. Ayres (1955) identified sources of microbial contamination and suggested that the storage life of the carcass depends on whether or not these organisms find the nutrients, humidity and temperature of their newfound residence to be satisfactory. Since reduced storage life can be attributed largely to the growth of bacteria and their elaboration of metabolic byproducts, numerous attempts have been made to create an environment detrimental to microbial growth. Patterson (1967) suggested that sanitation and clean handling could lower initial loads and identified cooling, chilling, washing and chlorination as methods for reducing bacterial damage. Patterson (1968, 1970 and 1972) investigated hot and cold water washes for curtailing spoilage and described significant reductions in bacterial count following treatments with 80° to 96° C water for periods of 2 minutes, with chlorinated (10 parts per million chlorine) water or with high pressure (150 pounds per square inch) spraying. Bailey (1971) reported that fan-jet spraying of carcasses with 60° C water and a surface impact of 0.15 (pound feet per square inch) or the use of chlorinated (15 to 357 ppm) water rinses were beneficial in reducing microbial growth and enhancing effective storage life. Mountney and O'Malley (1965) determined that acetic acid was an effective meat preservative for poultry but reported that it produced a pungent odor and skin discoloration. Carpenter (1972) and Biemuller, Carpenter and Reynolds (1973) suggested that strict sanitation procedures during processing followed by spraying of the carcass with acetic acid (pH = 2) could control bacteria on pork carcasses. The present study determined the effects of storage temperatures, decontaminating agents and wrapping materials on bacterial counts, shrinkage rates and palatability characteristics of lamb carcasses.

Experimental Procedure

Three experiments involving 214 lamb carcasses were conducted to determine the effects of various treatments on shrinkage, bacterial counts and palatability traits. The lambs were slaughtered at the Texas A&M University Meat Laboratory using conventional procedures. Treatments involving film wrapping, shrouding or application of decontamination agents were initiated immediately following spray-washing (60° C water at 40 psi) and carcasses were moved immediately thereafter into a designated cooler.

Experiment 1

Seventy-two lamb carcasses were individually assigned to treatments involving four decontamination procedures, three types of wrapping or two temperatures of storage. Lambs were randomly assigned to one of the following treatments: (A) Control, (B) 4% propionic acid rinse, (C) 0.02% chlorine rinse, (D)

singeing with direct flame, (E) high velocity air drying, (F) polyvinyl chloride (PVC) film shrouding, (G) PVC film mummy-wrapping, and (H) PVC film shrouding, 2 hours postmortem. Half of the carcasses in each treatment were stored in a 0° C cooler for the entire 120-hour period; the other half were placed in a 16° C cooler for the first 24-hour postmortem and moved to the 0° C cooler for the remainder of the 120-hour period. Propionic acid and sodium hypochlorite (chlorine) solutions were poured over the carcasses immediately before chilling. Carcasses were singed by directly flaming the entire external surface with a hog singeing device. High velocity air drying was accomplished by placing carcasses directly in front of a large electric fan. Data were collected for postmortem weight loss (shrinkage), bacterial count and palatability traits.

Experiment 2

Seventy-two lamb carcasses were randomly assigned to one of six treatments or to a control group to determine the effects of decontaminating agents on bacterial counts and subsequent palatability. Lambs were individually assigned to one of the following treatments: (I) Control, (J) 2 percent acetic acid rinse, (K) 0.02 percent chlorine rinse, (L) 0.02 percent chlorine plus 2 percent acetic acid rinse, (M) 2 percent propionic acid rinse, (N) 0.02 percent chlorine dioxide rinse, and (O) high temperature (85° C) and high pressure (70 psi) water spray. Chemicals used in treatments J, K, L, M and N were diluted to the proper concentrations, placed in 1-liter wash bottles and sprayed on the carcasses, using a fine mist nozzle adjustment. Spraying was continued over the entire external surface to achieve visible drip of solutions. All carcasses were stored in a 0° C cooler for 96 hours.

Experiment 3

Seventy lamb carcasses were randomly assigned to one of 13 treatments or to a control group to determine the effects of initial and subsequent treatments with decontaminating agents and wrapping with PVC film on bacterial counts. Lambs were individually assigned to one of the following treatments: (P) Control, (Q) 0.02 percent chlorine rinse immediately postmortem, (R) 0.02 percent chlorine dioxide rinse immediately postmorterm, (S) 0.02 percent iodophor rinse immediately postmortem, (T) 0.02 percent chlorine rinse 7 days postmortem, (U) 0.02 percent chlorine dioxide rinse 7 days postmortem, (V) 0.02 percent iodophor rinse 7 days postmortem, (W) PVC film mummy-wrapping immediately postmortem, (X) PVC film mummy-wrapping and 0.02 percent chlorine rinse immediately postmortem; (Y) PVC film mummy-wrapping and 0.02 percent chlorine dioxide rinse immediately postmortem, (Z) PVC film mummy-wrapping and 0.02 percent iodophor rinse immediately postmortem, (A') PVC film mummy-wrapping immediately postmortem and 0.02 percent chlorine rinse 7 days postmortem, (B') PVC film mummy-wrapping immediately postmortem and 0.02 percent chlorine dioxide rinse 7 days postmortem, and (C') PVC film mummy-wrapping immediately postmortem and 0.02 percent iodophor rinse 7 days postmortem. All carcasses were stored in a 0° C cooler for 192 hours.

Decontaminating Agents

All of the chemical agents used for bacteriostatic rinses were formulated in 1 gallon of distilled water. The specific mixtures were 0.02 percent chlorine, 0.4 fluid ounce of Purex (Purex Corporation Ltd., Lakewood, California); 0.02 percent chlorine dioxide, 1.2 fluid ounces of Oxine (Hess and Clark, Ashland, Ohio); 0.02 percent iodophor, 0.2 fluid ounce of Iokay (Meyer - Blanke Company, St. Louis, Missouri); 2 percent acetic acid, 2.5 fluid ounces of glacial acetic acid (Fisher Scientific Company, Fair Lawn, New Jersey); and 2 percent or 4 percent propionic acid, 2.5 or 5.0 fluid ounces of propionic acid (Celanese Chemical Corporation, New York) in 1 gallon of distilled water.

Bacterial Counts

In all experiments bacterial samples were taken from the subcutaneous fat on the cushion of the leg by use of a moist swab, 6.45 square centimeters sterile template and buffered rinse solution technique. Phosphate buffer was used in experiment 1; a phosphate buffer with the addition of Tween 20 and Asolectin (American Public Health Association, 1953) was used in experiments 2 and 3. The modified buffer solution was designed to disperse and inactivate any residual chlorine picked up by the swab to prevent its bacteriocidal activity during subsequent dilution and culture. Bacterial samples were obtained 120, 96 and 192 hours postmortem in experiments 1, 2 and 3, respectively, diluted in phosphate buffer, plated using total plate count agar, incubated at 5° C for 7 days and subsequently counted.

Palatability Tests

Individual chops were removed from the twelfth and thirteenth rib areas from carcasses in experiments 1 and 2. Each chop was cooked in a 175° C oven for 43 minutes and evaluated by a trained six-member sensory panel. Cooked *longissimus* muscle samples were evaluated for flavor, juiciness, tenderness and overall satisfaction by use of an 8-point hedonic scale (8 = extremely desirable; 1 = extremely undesirable) and for incidence of off-flavor by use of a 3-point scale (3 = no off-flavor; 1 = objectionable off-flavor). In experiment 1, an additional chop was cooked to 75° C in a 177° C oven, and three cores (1.27 centimeters) were used for Warner-Bratzler shear determinations.

Results and Discussion

Experiment 1

Shrink losses, bacterial counts and palatability ratings for lamb carcasses in experiment 1 are presented in Table 1. Smith and Carpenter (1973) reported that decreases in surface area and increases in subcutaneous fat were associated with decreased postmortem shrinkage in lamb carcasses. Since increases in fatness

TABLE 1. SHRINK LOSSES, BACTERIAL COUNTS AND PALATABILITY RATINGS FOR LAMB CARCASSES IN EXPERIMENT 1

Treatment	Treatment code	Shrink loss (percentage)		Bacterial count (log_{10})		Flavor rating[1]	Degree of off-flavor rating[2]
		Storage at 0° C[3]	Storage at 16° C[4]	Storage at 0° C	Storage at 16° C	Storage at 0° C	Storage at 0° C
Control (unprotected, untreated)	A	6.3	7.3	2.5	2.0	6.0	2.9
4 percent propionic acid rinse	B	6.5	7.1	2.0	0.4	5.3	2.6
0.02 percent chlorine rinse	C	5.9	6.1	TFTC[5]	0.2	5.8	2.7
Singeing with direct flame	D	6.2	6.5	2.2	2.2	5.9	2.8
High velocity air drying	E	6.8	7.1	0.4	TFTC[5]	6.1	2.9
PVC film shrouding, immediately postmortem	F	3.8	4.4	2.0	5.2	5.9	2.7
PVC film mummy-wrapping	G	3.2	3.8	4.4	6.9	5.8	2.8
PVC film shrouding, 2 hours postmortem	H	4.6	4.4	2.3	4.6	5.9	2.8

[1] Means based on an 8-point scale (8 = extremely desirable; 1 = extremely undesirable).

[2] Means based on a 3-point scale (3 = no off-flavor; 1 = objectionable off-flavor).

[3] Carcasses were stored in a 0° C cooler for the entire 120-hour interval.

[4] Carcasses were stored in a 16° C cooler for 24 hours and subsequently in a 0° C cooler for 96 hours.

[5] TFTC = too few to count.

are associated with decreases in cutability and monetary value, the use of plastic wrapping materials to reduce shrinkage may be advantageous. The use of PVC film as a multi-layered (mummy) wrap was associated with the greatest reduction in postmortem shrinkage (Table 1). Single layers of PVC (shrouds) were most effective when applied immediately postmortem, but both immediate and delayed shrouding substantially reduced shrinkage. Carcasses stored in PVC film evidenced surface moisture accumulation throughout the 5-day storage period and exhibited an extremely attractive white surface. Conversely, those carcasses treated with 4 percent propionic acid were dry and yellow to tan in color (subcutaneous fat cover), and shrinkage losses were relatively high.

Substantial reductions in bacterial counts were associated with the use of chlorine rinses and with high velocity air drying at both storage temperatures (Table 1). The use of a 4 percent propionic acid rinse was effective in reducing bacterial counts at the higher (16° C) but not at the lower (0° C) storage temperature. Both chlorine and propionic acid are bacteriostatic or bacteriocidal, while high velocity air movement dries the surface, lowers the surface water-activity (Aw) and reduces the growth of bacteria. Conversely, PVC film protects the surface from dehydration and/or evaporative loss, increases the Aw and thereby enhances bacterial growth. These data reveal substantial increases in bacterial growth on lamb carcasses which were mummy-wrapped with PVC film at both storage temperatures. The use of PVC film as a shroud enhanced bacterial growth (compared with control carcasses) only at the higher (16° C) storage temperature.

Sensory panel ratings for flavor of cuts from lamb carcasses in experiment 1 are presented in Table 1. The use of 4 percent propionic acid was associated with decreased flavor and an increased incidence of off-flavor. These, plus the high shrinkage losses and off-colored fat for carcasses treated in this manner suggest that the concentration of propionic acid used was too high to warrant industrial application. In general, the effects of carcass treatments on the flavor characteristics of lamb were minor. A variety of procedures probably can be used to minimize bacterial counts without causing substantial decreases in eating satisfaction.

Effects of differences in storage temperature on palatability traits, bacterial counts, shrink losses and sarcomere lengths for lambs in experiment 1 are presented in Table 2. Elevated storage temperatures (16° C) have been used effectively in New Zealand for conditioning lamb carcasses to be used in the export trade. In the present study, storage of lamb carcasses at 16° C for 24 hours immediately postmortem was associated ($P<.05$) with increased tenderness ratings and decreased shear force requirements. Unfortunately, the use of elevated storage temperature also was associated with increased shrinkage losses ($P>.05$) and enhanced bacterial growth ($P<.05$). The merit of using elevated storage temperature would depend on the relative monetary advantage of enhanced tenderness in relation to the loss in weight and increased bacterial growth. At present, it is doubtful that the tenderness increase would be recognized by any increase in market value.

Experiment 2

Bacterial counts and palatability ratings for lamb carcasses in experiment 2 are presented in Table 3. Chlorine, chlorine dioxide and combined chlorine and acetic acid rinses were associated with reductions in bacterial count. Chlorine supplied as 0.02 percent sodium hypochlorite resulted in significant ($P<.05$) reductions in bacterial count as compared to control lambs, lambs treated with chlorine dioxide and lambs

TABLE 2. EFFECTS OF DIFFERENCES IN STORAGE TEMPERATURE ON PALATABILITY TRAITS, BACTERIAL COUNTS, SHRINK LOSSES AND SARCOMERE LENGTHS FOR LAMB CARCASSES IN EXPERIMENT 1

Trait	Storage temperature	
	0° C	16° C
Flavor rating[1]	5.8[d]	5.7[d]
Tenderness rating[1]	5.2[e]	5.8[d]
Overall satisfaction rating[1]	5.3[d]	5.5[d]
Bacteria count ($\log_{10}$)	2.0[d]	2.6[e]
Shrink loss (%)	5.5[d]	6.0[d]
Sarcomere length (microns)[2]	1.7[d]	1.8[d]
Shear force value (kg)[3]	3.3[e]	2.9[d]

[1] Means based on an 8-point scale (8 = extremely desirable; 1 = extremely undesirable).

[2] The average length of 500 sarcomeres from each *longissimus* muscle sample. Muscle was homogenized in cold 0.25 M sucrose solution for 20 seconds and measured by use of a filar micrometer.

[3] Three cores (1.27 centimeters) were removed from longissimus muscle samples following cooking to 75° C in a 177° C oven and subsequent cooling to room temperature.

[de] Means on the same line bearing different superscripts differ significantly ($P<.05$).

sprayed with high temperature and high pressure water. Patterson (1968) suggested the use of 10 ppm of chlorine in water for washing sheep carcasses. Bailey (1971) concluded that the use of chlorinated water was beneficial at all concentrations from 15 to 350 ppm. In the present study, the use of high temperature and high pressure water was the least effective method for reducing bacterial counts. Patterson (1968) found no significant difference in bacterial counts from carcasses which were sprayed with hot water and/or cold water but Patterson (1970) demonstrated significant reductions in bacterial counts using an 80°-96° C water wash for 2 minutes. Patterson (1972) compared water pressures of 150, 250 and 350 psi and reported that the use of 150 psi resulted in the lowest total counts since the higher pressures tended to drive the bacteria into the tissue. In the present study, 2 percent solutions of propionic acid or acetic acid were ineffective in reducing bacterial counts. Bailey (1971) showed that the majority of the systems presently used for cleaning lamb carcasses are ineffective in removing bacteria. It is, of course, more advisable to avoid contamination than to try to remove bacteria after slaughter but research is needed to cope with the existing problems of contamination and subsequent spoilage.

Taste panel ratings for lamb carcasses in experiment 2 are presented in Table 3. Mean ratings for off-flavor did not differ significantly among treatments. Flavor ratings for chops from carcasses treated with acetic acid or sprayed with hot water were significantly higher than those for chops from untreated lambs. On the basis of these data, there is little justification for discouraging the use of decontaminating agents on the supposition that they will affect palatability.

Experiment 3

Bacterial counts for lamb carcasses are presented in Table 4. Rinsing carcasses immediately postmortem with solutions containing 0.02 percent chlorine, chlorine dioxide or iodophor was extremely effective in reducing bacterial counts on the eighth day postmortem. Wrapping of carcasses immediately postmortem with PVC film substantially increased bacterial counts even when 0.02 percent solutions of chlorine, chlorine dioxide or iodophor were used in the carcass washing procedure. Efforts to decontaminate carcasses which were unprotected or wrapped in PVC film after 7 days of storage revealed that 0.02 percent solutions of chlorine or chlorine dioxide reduced bacterial counts by approximately one log unit. These results suggest that decontaminating agents are more effective in reducing bacterial growth if they are applied immediately postmortem to carcasses that will be stored without the application of wrapping materials.

TABLE 3. BACTERIAL COUNTS AND PALATABILITY RATINGS FOR LAMB CARCASSES IN EXPERIMENT 2

Treatment	Treatment code	Bacterial count ($\log_{10}$)	Flavor rating[1]	Degree of off-flavor rating[2]
Control (untreated)	I	2.4[d]	5.7[f]	2.8[d]
2 percent acetic acid rinse	J	2.0[de]	6.5[de]	2.8[d]
0.02 percent chlorine rinse	K	1.3[e]	6.0[ef]	2.9[d]
0.02 percent chlorine plus 2 percent acetic acid rinse	L	1.5[de]	6.2[def]	3.0[d]
2 percent propionic acid rinse	M	2.2[de]	6.1[def]	2.7[d]
0.02 percent chlorine dioxide rinse	N	1.8[de]	6.1[def]	2.7[d]
High temperature, high pressure water spray[3]	O	2.3[d]	6.7[d]	2.9[d]

[1] Means based on an 8-point scale (8 = extremely desirable; 1 = extremely undesirable).

[2] Means based on a 3-point scale (3 = no off-flavor; 1 = objectionable off-flavor).

[3] Water temperature was 85° C; water pressure was 70 psi.

[def] Means in the same column bearing different superscripts differ significantly ($P<.05$).

TABLE 4. BACTERIAL COUNTS FOR LAMB CARCASSES IN EXPERIMENT 3

Treatment code	Treatment immediately postmortem	Carcass wrap immediately postmortem	Treatment on the 7th day postmortem	Bacterial count (log_{10}) on the 8th day postmortem
P	Control	None	None	3.2
Q	0.02 percent chlorine	None	None	TFTC[1]
R	0.02 percent chlorine dioxide	None	None	TFTC
S	0.02 percent iodophor	None	None	TFTC
T	None	None	0.02 percent chlorine	2.2
U	None	None	0.02 percent chlorine dioxide	2.1
V	None	None	0.02 percent iodophor	1.8
W	None	PVC	None	5.6
X	0.02 percent chlorine	PVC	None	5.9
Y	0.02 percent chlorine dioxide	PVC	None	4.7
Z	0.02 percent iodophor	PVC	None	4.4
A′	None	PVC	0.02 percent chlorine	4.3
B′	None	PVC	0.02 percent chlorine dioxide	4.5
C′	None	PVC	0.02 percent iodophor	5.8

[1] TFTC = Too few to count.

Attempts to capitalize upon the reduced postmortem shrinkage and enhanced physical appearance associated with the use of carcass wraps and the substantial reduction in bacterial growth evidenced for bacteriostatic rinse solutions by combining the treatments (carcass wrapping plus decontaminating agents, immediately postmortem) met with only limited success.

Conclusions

(1) The influence of surface Aw in determining bacterial growth on lamb carcasses was evidenced by comparisons between high velocity air drying and PVC film wrapping treatments. Drying of the surface was associated with substantial decreases in bacterial count, while the use of PVC film promoted surface accumulation of moisture, improved the physical appearance of carcasses, increased the Aw and greatly increased bacterial growth.

(2) Storage of lamb carcasses at 16° C for 24 hours immediately postmortem was associated with increased tenderness but also with increased bacterial growth (especially when carcasses were wrapped in PVC film).

(3) The use of decontaminating agents formulated as dilute solutions of chlorine was associated with substantial reductions in bacterial count, yet had no appreciable effect on the flavor of lamb chops. Excessively high concentrations of propionic acid resulted in discolored fat surfaces on treated carcasses and decreased palatability of subsequent retail cuts.

(4) Decontaminating agents were most effective in reducing bacterial growth when they were applied immediately postmortem to carcasses that were stored without the subsequent application of PVC film. Use of decontaminating agents after 7 days of storage was associated with a decimal reduction in bacterial counts.

(5) Combined use of PVC film and decontaminating agents immediately postmortem, in an attempt to control both shrinkage and microbial growth, did not produce consistent reductions in bacterial counts.

Acknowledgment

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PR-3298

Comparison of the Palatability Of Longissimus Muscle From Five Meat Animal Species

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and Z. L. Carpenter

SUMMARY: Five sensory panels, involving 269 members, were used to compare palatability attributes of muscle samples from five meat animal species. *Longissimus* muscle (ribeye or loineye) samples from 109 goat carcasses, 71 lamb carcasses, 30 pork carcasses, 34 beef carcasses and 1 horse carcass were cooked to an internal temperature of 75° C and served to untrained members of five sensory panels. Personnel comprising the sensory panels did not know the purpose of the test or that the samples were from animals of different species. Beef, pork and lamb were similar in flavor desirability, with a general preference expressed for pork. Goat meat was usually less desirable ($P<.05$) than pork but was not decidedly different in flavor from samples of beef or lamb. Lamb *longissimus* muscle was considered most desirable in juiciness; muscle from goat carcasses compared favorably with that from the other meat animal species. Meat from lamb carcasses was decidedly more tender than muscle from beef, horse or goat carcasses and was most comparable to pork muscle in tenderness attributes. Goat meat was definitely less tender than lamb, beef or pork in the majority of the panel tests. Overall satisfaction ratings revealed that beef, pork, and lamb were similar in desirability. Goat muscle was less desirable than lamb, beef and pork but (in a single comparison) was more satisfactory overall than was horse meat. These data suggest that goat meat is not interchangeable with meat from the other species with regard to palatability attributes.

Introduction

Attempts to identify potential markets for the meat from Angora or Spanish goats are presently centered upon the development of grade standards for cabrito, kid, yearling and mature goat carcasses. Previous research (Eggen *et al.*, 1971a and 1971b and Smith, Berry and Carpenter, 1972) has involved studies of dressing percent, cutability, boning yield and replacement of beef with goat meat in frankfurters. A prerequisite to identification of grade standards is a determination of the ultimate utility and value of goat meat in relation to that from meat animal species which more commonly form the bulk of the domestic meat supply.

Consumption of goat meat will increase only (1) if the palatability is unique and thus satisfies the demand of a specific segment of the consuming public, or (2) if the price is equitable with the demand for meat of less satisfactory palatability, (3) if such meat can be effectively substituted for meat from other species in processed meat products, and (4) if directed marketing can be facilitated to channel such meat into appropriate trade areas and to specific consumers. Goat meat is eaten in many areas of the Southwest. Cabrito is commonly used for barbecue, and mature goat meat is incorporated into sausage (Chorizo) or chili con carne. The comparative palatability of goat meat in relation to meat from other farm animal species is not presently known. This report summarizes research designed to compare the palatability attributes of *longissimus* muscle samples from five species of meat animals.

Experimental Procedure

Longissimus muscle (ribeye or loineye) samples were obtained from the carcasses of 109 goats, 71 lambs, 30 pigs, 34 beeves and 1 horse. Five sensory panels comprised of 72, 47, 21, 35 and 94 untrained members evaluated the flavor, juiciness, tenderness and overall satisfaction of each sample. Each panel member was instructed in the use of a hedonic rating scale (8=like extremely, 1=dislike extremely), but they were not informed of the purpose of the test and did not know that the samples were from animals of different species.

Each sample was cooked in a 177° C oven to an internal temperature of 75° C. Samples derived from the same anatomical region in each carcass were served, while still warm, to individual panel members. Since only 1 horse carcass was available, samples of goat, lamb, beef and pork for use in sensory panel V comparison were carefully selected in an attempt to remove quality-level bias. Samples of the other four species had, as nearly as possible, the same quality-indicating characteristics (muscle color, marbling, skeletal characteristics and texture). Nevertheless, the results comparing horse meat with that from carcasses of the other species may not be valid.

Results and Discussion

Flavor ratings for *longissimus* muscle samples from five meat animal species are presented in Table 1. Meat from Angora goat carcasses was rated lower ($P<.05$) in flavor than meat from pork carcasses in comparisons by sensory panels I and II and was less desirable than lamb, beef or pork in sensory panel comparison I. Muscle samples from Spanish goat carcasses did not differ significantly in flavor desirability from samples of lamb (panels III, IV and V), beef (panels III, IV and V) or horse (panel V) meat and were less desirable than samples from pork carcasses in one (panel V) of three sensory panel comparisons. Differences in flavor among lamb, beef and pork samples were much less definitive. Pork was equal to or more flavorful than beef in every comparison and was significantly more desirable than lamb in two panel tests. In a series of investigations of beef, pork, lamb and whale meat, Hornstein, Crowe and Sulzbacher (1960, 1963) and Hornstein and Crowe (1960, 1963)

TABLE 1. FLAVOR RATINGS FOR LONGISSIMUS MUSCLE SAMPLES FROM FIVE MEAT ANIMAL SPECIES

	Sensory panel				
Species	I (n=72)	II (n=47)	III (n=21)	IV (n=35)	V (n=94)
Goat	5.3[c]	4.6[b]	6.1[a]	6.1[a]	6.3[bc]
Lamb	6.8[a]	4.9[b]	6.7[a]	6.9[a]	6.0[c]
Beef	6.1[b]	5.2[b]	7.3[a]	6.5[a]	6.6[ab]
Pork	6.1[b]	6.0[a]	6.3[a]	6.8[a]	7.0[a]
Horse					5.9[bc]

[abc] Means bearing different superscripts differ significantly (P<.05).

concluded that an identical basic meaty aroma is associated with the lean portion of these meats and that species flavor differences reside in the fat. Gaili *et al.* (1972) compared Sudan Desert sheep and goats and concluded that there was no difference among these two species in flavor.

The data of the present study suggest that *longissimus* muscle from goat carcasses is not decidedly different in flavor from that of beef or lamb carcasses but that goat meat (especially that from Angora carcasses) tends to be less acceptable than pork meat in flavor desirability. Beef, pork and lamb were similar in flavor desirability, with some suggestion that pork is most desirable in flavor.

Juiciness ratings for muscle samples from goat, lamb, beef, pork and horse carcasses are presented in Table 2. Goat meat was significantly more juicy than horse meat in panel comparison V and did not differ in juiciness from samples of pork in any of the five sensory panel tests. Moreover, goat meat was statistically equivalent in juiciness ratings to lamb and beef in three and four sensory panel comparisons, respectively. These data suggest that *longissimus* muscle from goat carcasses compares favorably in juiciness to that of muscle from the other meat animal species, with some evidence that it may be less juicy than lamb but more juicy than horse meat. Gaili *et al.* (1972) reported that meat from young goats was juicier than that from young sheep, but that there was no difference in juiciness between species when meat from yearling or mature carcasses was compared. Lamb was as juicy as beef in two panel tests and more juicy in two panel tests. It was as juicy as pork in two panel tests and more juicy in three panel tests. Generally lamb was the most desirable species with regard to juiciness characteristics of the *longissimus* muscle.

Tenderness ratings for *longissimus* muscle samples derived from the carcasses of five meat animal species are recorded in Table 3. Goat meat was less tender than lamb, beef or pork in four, four and four, respectively, sensory panel comparisons. A single comparison suggested that goat meat was not significantly less tender than lamb or pork and that goat muscle was more tender than was horse muscle. *Longissimus* muscles from lamb carcasses were significantly (P<.05) more tender than that from beef carcasses in every sensory panel comparison. Pork meat was more tender

TABLE 2. JUICINESS RATINGS FOR LONGISSIMUS MUSCLE SAMPLES FROM FIVE MEAT ANIMAL SPECIES

	Sensory panel				
Species	I (n=72)	II (n=47)	III (n=21)	IV (n=35)	V (n=94)
Goat	5.6[b]	5.2[a]	5.8[ab]	4.5[b]	6.3[b]
Lamb	7.0[a]	5.9[a]	6.8[a]	6.9[a]	6.2[b]
Beef	5.7[b]	5.7[a]	5.8[ab]	5.0[b]	6.8[a]
Pork	5.3[b]	5.2[a]	5.4[b]	5.0[b]	6.0[b]
Horse					5.2[c]

[abc] Means bearing different superscripts differ significantly (P<.05).

than beef and equal to or more tender than lamb in three sensory comparisons. Miller *et al.* (1944) found that goat meat was rated as neutral rather than tender or tough in both laboratory and field panel comparisons. Moreover, goat meat that was served in barbecued form was more tender than was goat meat served as broiled chops.

Data of the present study indicated that *longissimus* muscle from the lamb was decidedly more tender than that from beef, horse and goat carcasses, and most comparable to pork muscle in tenderness attributes. Goat meat was decidedly less tender than lamb, beef or pork in a majority of the panel tests. The latter finding is in agreement with Gaili *et al.* (1972) who reported that meat from yearling goats was much less tender (P<.05) than that from yearling sheep.

Overall satisfaction ratings for *longissimus* muscle samples from the five meat animal species are presented in Table 4. Beef, pork and lamb had similar overall satisfaction ratings, with lamb and pork having significantly higher ratings than beef in two and one comparisons, respectively. Goat meat was less desirable than lamb, beef and pork in four, four and three panel tests, respectively. Horse meat was the least (P<.05) desirable meat in panel comparison V, which reflected its relatively low ratings for flavor (Table 1) and tenderness (Table 3) and its decided lack of juiciness (Table 2). The low overall satisfaction ratings for goat meat were largely a result of its comparative toughness (Table 3). The data of the present study

TABLE 3. TENDERNESS RATINGS FOR LONGISSIMUS MUSCLE SAMPLES FROM FIVE MEAT ANIMAL SPECIES

	Sensory panel				
Species	I (n=72)	II (n=47)	III (n=21)	IV (n=35)	V (n=94)
Goat	4.2[d]	4.9[c]	5.0[c]	4.4[c]	6.7[ab]
Lamb	7.9[a]	6.7[a]	7.5[a]	7.5[a]	6.5[b]
Beef	5.9[c]	5.8[b]	6.2[b]	6.0[b]	5.8[c]
Pork	6.6[b]	6.0[ab]	6.3[b]	6.9[a]	7.1[a]
Horse					5.7[c]

[abcd] Means bearing different superscripts differ significantly (P<.05).

TABLE 4. OVERALL SATISFACTION RATINGS FOR LONGISSIMUS MUSCLE SAMPLES FROM FIVE MEAT ANIMAL SPECIES

	Sensory panel				
Species	I (n=72)	II (n=47)	III (n=21)	IV (n=35)	V (n=94)
Goat	4.9[c]	4.5[b]	5.8[b]	5.3[c]	6.5[ab]
Lamb	7.0[a]	5.5[a]	7.1[a]	7.0[a]	6.2[b]
Beef	6.0[b]	5.3[a]	7.2[a]	6.2[b]	6.3[b]
Pork	6.0[b]	5.6[a]	6.3[ab]	6.3[ab]	6.8[a]
Horse					5.7[c]

[abc]Means bearing different superscripts differ significantly ($P<.05$).

indicate that goat meat is not interchangeable with meat from other species (of the same approximate maturity and fatness levels) with regard to palatability attributes.

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PR-3299

Evaluation of an Injectable Anthelmintic for Sheep

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SUMMARY: The relative safety and effectiveness of an injectable form of levamisole with sheep was evaluated. Administration of levamisole anthelmintic by subcutaneous injection was as effective in reducing the number of worm eggs per gram of feces as the standard drench form of the drug. An injection of 1.5 millimeters of an 18.2-percent solution of levamisole phosphate resulted in some tissue reaction — swelling of the injection site was found in 23 of 32 lambs observed 7 days after treatment. However, there was a rapid reduction in the incidence of swelling. Fourteen days after injection, 24 of the 32 lambs showed no reaction, and at 28 days, a slight palpable swelling was found in only one of the 32 lambs examined. No abscesses were observed when the lambs were slaughtered 62 days after injection.

Introduction

Levamisole hydrochloride, *l*-2,3,5,6-Tetrahydro-6-phenyl-imidazo [2,1-b]-thiazole hydrochloride, has been demonstrated to be a safe and effective broad spectrum anthelmintic for use with lambs (American Cyanamid, Technical Bulletin, 27-2). At present it is approved only for administration to sheep as a drench, at the recommended dose of 8 milligrams per kilogram of live weight in a water solution.

An injectable form (levamisole phosphate) is approved for subcutaneous injection in cattle. Because of the convenience of this form of anthelmintic administration, there is considerable interest among sheep producers in obtaining Food and Drug Administration (FDA) clearance for use of this material for sheep.

The relative safety and effectiveness of an injectable form of levamisole with sheep were evaluated.

Experimental Procedure

Two hundred eighty-eight Rambouillet wether feeder lambs were subjected to three treatments (control, Tramisol drench and Tramisol injectable) superimposed as a split-plot comparison in a nutrition experiment conducted during the fall of 1973. The study involved 48 pens of lambs with 6 lambs per pen. Two lambs in each pen received one of the anthelmintic treatments.

The drench was prepared by dissolving 52 grams of commercially available Tramisol(R) soluble drench powder (containing 46.8 grams of levamisole hydrochloride activity) in 1 gallon of water. Three-fourths of an ounce of the drench was given to each of 96 lambs using an automatic drench syringe.

An additional 96 lambs were injected subcutaneously on the right side of the neck with 1.5 milliliters of an 18.2 percent solution of injectable Tramisol (R) as levamisole phosphate (each milliliter of this preparation contained the equivalent of 182 milligrams of levamisole hydrochloride). The injection was made with an automatic dose syringe. To simulate the situation that would prevail under ranch or feedlot conditions, neither the needle nor the injection site was cleaned with alcohol. However, care was taken to see that the needle was relatively clean and sharp.

The lambs were observed after treatment for signs of adverse reactions to treatments. Injection sites

were examined at 7, 14 and 28 days post injection for signs of tissue reaction and swelling. Carcasses were examined for evidence of abscesses on the neck when the lambs were slaughtered, approximately 62 days after injection.

Fecal samples were obtained before injection and at 28 days after injection from a representative number of lambs (36) for assessment of gastrointestinal nematode load. A flotation technique for measurement of the number of worm eggs per gram of feces was used.

Results and Discussion

Average initial live weights and live weight gains during the 56-day feeding period are given for each of the treatment groups in Table 1. Lambs receiving either of the two anthelmintic treatments gained about 1 pound more per lamb than the control lambs during the 56-day feeding period. However, this difference was not significant (P>.10).

The average number of worm eggs per gram of feces measured initially was considerably less than the number of gastrointestinal nematodes considered a case of clinical parasitism (Marsh, 1965). Usually, total egg counts in clinical parasitism will run higher than 1,000 eggs per gram of feces. Only one of the lambs examined had a fecal worm egg count of 1,000. In addition, all of the lambs appeared thrifty, with no indication of parasitism.

Examination of the feces at 28 days after administration of the anthelmintic treatment revealed a significant reduction (P<.05) in the number of worm eggs resulting from the administration of Tramisol(R). Both methods of administration, drench and subcutaneous injection, appeared to be equally effective (Table 1).

Some tissue reaction was observed at the site of injection. (Table 2). No reaction was observed in 28.1 percent of the lambs examined 7 days after the injection. Varying degrees of swelling at the injection site were evident in the remainder of the lambs examined. No reaction was observable in 75.0 percent of the lambs at 14 days after treatment. At 28 days a slight, palpable swelling was observable in only one of the 32 lambs examined.

Aside from the slight, brief swelling, no adverse effects resulted from the anthelmintic injection. The degree of swelling was similar to but did not last as long as that for the enterotoxemia vaccine (*Clostridium perfringens*, Type D bacterin-toxiod) also given to these lambs at the initiation of the experiment. No abscesses were found on the necks when the lambs were slaughtered about 62 days after the anthelmintic injections were administered. However, there was a large incidence of abscesses associated with the enterotoxemia injection sites.

TABLE 1. INITIAL WEIGHT, LIVE WEIGHT GAIN, AND NUMBER OF WORM EGGS PER GRAM OF FECES

	Anthelmintic treatment			
Criterion	Control	Drench	Injection	P
Lambs, number	92	91	92	
Initial weight, lb.	73.0	70.4	73.2	
Live weight gain, lb./56 day	25.9	27.0	27.3	P<.10
Lambs, number	11	8	10	
Initial, EPG[1]	232	288	240	
Final, EPG	186	25	0	
Change, EPG	-46	263	-240	P<.05

[1] Eggs per gram.

TABLE 2. SUMMARY OF TISSUE REACTIONS OBSERVED AT SITE OF ANTHELMINTIC INJECTION

	Days postinjection					
	7		14		28	
Observed response	No.	Percent[4]	No.	Percent	No.	Percent
Lambs, number	32		32		32	
No reaction	9	28.1	24	75.0	31	96.9
Slight swelling[1]	7	21.9	5	15.6	1	3.1
Swelling, ≤ ½" diameter[2]	13	40.6	3	9.4	0	0.0
Swelling, ≥ ½" diameter[3]	3	9.4	0	0.0	0	0.0

[1] Swelling was palpable but not visually noticeable (lambs were shorn approximately 7 days prior to the start of the experiment).

[2] Visible swelling, up to approximately ½" in diameter.

[3] Visible swelling, greater than ½" in diameter.

[4] Number of lambs in each category as a percentage of the total number observed.

Acknowledgments

Levamisol phosphate (Tramisol(R) injectable, 18.2 percent, containing 182 milligrams levamisole hydrochloride equivalent per milliliter) was provided through the courtesy of P. R. Zimmer and R. L. DeLay, American Cyanamid Co., Agricultural Division.

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PR-3300

Evaluation of an Insecticide For Control of Goat Lice

C. A. Taylor, Jr., J. R. Stewart and Maurice Shelton

SUMMARY: Two trials were conducted to evaluate an insecticide (Chlorfenvinphos) for control of lice on Angora goats. The insecticide proved highly effective and was comparable to malathion for lice control. In the one trial in which quantitative data were obtained, lice control did not improve animal performance.

Introduction

Satisfactory control of lice remains a continuing problem for Angora goat producers. A new insecticide, Chlorfenvinphos, was evaluated for effectiveness in the control of this parasite and to determine whether lice control would improve the performance of Angora goats.

Experimental Procedure

Fifty-seven yearling Angora goats, used in the first study, were sheared and placed on feed in March and remained on full feed for the duration of the test. Of these, 24 doe yearlings were sprayed with Chlorfenvinphos, 20 bucks were sprayed with malathion and 13 does were left untreated as a control. In the second study, 24 Angora nannies were sheared and separated into equal groups. One group was sprayed with Chlorfenvinphos insecticide, while the other was used as a control. In each test the treatment groups were maintained throughout the study in separate pens or pastures in an attempt to reduce reinfestation.

Lice counts were made once before treatment, every 10 days for 2 periods and then monthly for 2 months after treatment. The lice were counted by two people, each counting the number of lice visible in a 1-inch part of the hair on five areas (head, neck, shoulder, side and britch), totaling 10 counts per goat. The louse involved was the biting louse *Bovicola limbata,* but it is not known if this was the only species present.

Results

Chlorfenvinphos and malathion are both extremely effective insecticides for lice control on Angora goats. Both caused a reduction in the lice count per goat to nearly zero (Table 1).

TABLE 1. AVERAGE LICE COUNTS FOR FIVE AREAS

Treatment	No. animals	Number of lice per five areas: Prior to treatment	Post treatment			
		FIRST STUDY				
		3/30	4/9	4/20	5/18	6/21
Malathion	20	23.0	0.2	0.1	0.0	0.1
Chlorfenvinphos	24	12.0	0.0	0.0	0.2	0.0
Control (no treatment)	13	12.0	11.2	13.2	8.7	10.0
		SECOND STUDY				
		9/18	10/1	10/10	12/19	
Chlorfenvinphos	12	20.3	0.0	0.0	.33	
Control (no treatment)	12	24.7	18.0	20.6	14.00	

The control of lice did not improve the performance of goats, since the fleece weights of the two groups were the same (Table 2). The treated goats actually gained less than the untreated group; however, one of the reasons for lice control is to prevent rubbing or scratching which mats or tangles the fleece. It should be considered that more than one species of lice may be found on goats and that, under other conditions, an animal response might be obtained.

TABLE 2. WEIGHT GAINS AND FLEECE WEIGHTS OF TREATED AND UNTREATED DOES

Treatment	No. animals	Total gain, lb.	Fleece weight, lb.
Chlorfenvinphos	24	24.3	3.8
Control (no treatment)	13	26.4	3.8

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Texas Range Station, BARNHART

Texas A&M University-Tarleton Experiment Station at STEPHENVILLE
Texas A&M University Fruit Research-Demonstration Station at MONTAGUE

Blackland Research Center at TEMPLE

Texas A&M University Agricultural Research and Extension Center at UVALDE

Texas A&M University Agricultural Research and Extension Center at WESLACO

Texas A&M University-Texas A&I University Cooperative Research Unit at WESLACO

Texas A&M University Plant Disease Research Station at YOAKUM

The Texas Agricultural Experiment Station, J. E. Miller, Director, College Station, Texas

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