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RESEARCH REPORTS

Sheep and Goat, Wool and Mohair, 1992

The Texas Agricultural Experiment Station
...es Lee, Interim Director
...as A&M University System
...ation, Texas

Foreword

The 1992 Sheep and Goat/Wool and Mohair Consolidated Progress Report has been prepared by Texas Agricultural Experiment Station scientists to communicate current research activities and results to those involved in all phases of the sheep and goat industry. Our objective is to get results to the industry as rapidly as possible.

Three different types of reports have been prepared: 1) Research Briefs, which document initial research activity, provide justification and research approach, and report only limited results; 2) Progress Reports, based on at least one completed research trial, with data reported and discussed; and 3) a few more comprehensive review-type reports, which summarize several research trials conducted to provide data on a specific topic. More detailed information on any subject in this report may be obtained by contacting the responsible scientist(s) directly.

Sheep and goat research in Texas is a consolidated effort involving the scientists working at College Station, San Angelo, Sonora, and other field research sites. Scientists in Texas maintain close communication with scientists in other states, including those with the USDA. Additionally, linkages are established with research organizations in other countries where sheep and goat research is being conducted. Through this network, we maintain a prompt awareness of new developments and emerging technology that may be useful in Texas. The research program maintains relationships with private organizations involved with animal health care products; feed supplements; ration additives; growth promotants; wool, mohair, and lamb processing and marketing; and other products and concepts that may be useful in sheep and goat production.

Research is carefully targeted to address priority needs. The Texas Agricultural Experiment Station maintains a 5-year research plan in coordination with the sheep and goat industry. This research plan is reviewed annually with staff or members of the Texas Sheep and Goat Raisers Association, the Mohair Council, and others. This provides an organized approach and still allows for attention to new needs or shifts in priorities in the industry.

The current plan lists the following research needs for the industry:

1. Develop management schemes for optimal productivity under prevailing conditions.
2. Improve consumer acceptance of meat and fiber.
3. Decrease predation losses.
4. Develop objective processes to characterize meat and fiber from sheep and goats.
5. Improve animal health by controlling parasites, infectious diseases, and toxic and harmful plants.

Texas leads the nation in both sheep and goats. These animals play an important and unique role in obtaining maximum production and income from Central and West Texas rangelands. Therefore, most rangeland in the Edwards Plateau and some of the Trans-Pecos and southern edge of the Southern Rolling Plains regions are grazed by a mixture of cattle with sheep and/or goats. There is also considerable opportunity to expand this industry in farming areas where they can make efficient use of waste lands, glean cropland, and utilize available labor. The high production potential of both sheep and goats can be maximized under these optimum conditions.

The primary objective of the TAES research program is to provide new technology to continue to improve the productivity and profitability of this important Texas industry.

Carl Menzies, Resident Director
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Sheep and Goat, Wool and Mohair, 1992

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Contents

Wool, Mohair, and Cashmere Production, Quality, and Value

Production, Evaluation, and Marketing of Lamb Meat

Other

Chemical Contents of Guajillo Can Affect Release of Luteinizing Hormone (LH) in Sheep

B.B. Carpenter, T.D.A. Forbes, D.R. Tolleson, and R.D. Randel

Summary

Intravenous injections of the guajillo amine N-methyl-β-phenetyl-amine (NMPA) were given to Rambouillet wethers to evaluate effects on both adrenaline and noradrenaline as well as on the reproductive hormone LH, or luteinizing hormone. Treated animals showed a more rapid noradrenaline response than did control animals. Fewer treated versus control animals exhibited an LH response when challenged with releasing hormone for LH. Thus, inhibition of LH appears to be associated with noradrenaline response to NMPA. We do not know at this point how much guajillo must be ingested under grazing conditions to produce NMPA suppression of LH and overall reproductive function.

Introduction

Guajillo (*Acacia berlandieri*) is a leguminous shrub familiar to many operators in South Texas and northern Mexico. It is commonly browsed by domestic livestock as well as by wild herbivores. Over-consumption might occur when complimentary forage is limited and has been reported to cause problems with locomotor coordination in the hind legs of sheep and goats, a condition commonly referred to as "guajillo wobbles" or "limber leg" (5).

Several types of plant chemicals known broadly as "plant amine" are known to occur in guajillo (2). Dosage trials have shown that certain of these amines can cause overstimulation of the animal's own nervous system resulting in excessive release of noradrenaline into the peripheral blood (3). This has been suggested as the mechanism involved in "guajillo wobbles." Catecholamine, noradrenaline (NA), and adrenaline (AD) are known to also have effects on reproductive hormones at the level of the brain where luteinizing hormone, or LH, is released by the pituitary (1). Egg development in the female, as well as sperm development in the male, is dependent on LH. Therefore, catecholamine have the potential to affect the reproductive process indirectly. Forbes et al. (1991) reported lowered pregnancy rates in Angora nannies injected with N-methyl-β-phenethylamine (NMPA), an amine found in guajillo. Lowered ovarian progesterone production was also observed.

This study proposed to determine whether NMPA could affect LH release from the pituitary and, if so, whether catecholamines are involved. Our ultimate goals are to determine the effects, if any, of plant amine on reproduction and performance in grazing and browsing livestock.

Experimental Design

Twenty-seven Rambouillet wethers were used in the study. Castrated males were used so that brain hormones could be more clearly studied without possibly confounding effects from gonadal hormones.

To accustom the animals to the test environment, they were placed in stanchions and allowed access to food for 30 min. each day for 1 week before commencement of the experiment. The animals were fitted with an indwelling jugular canulae the evening before blood sampling. The canulae allowed for blood sampling as well as for infusions of both NMPA and a physiological dosage (500 mg) of luteinizing hormone releasing hormone (LHRH). Under normal circumstances, LHRH causes a release of LH from the pituitary.

The animals weighed an average of 123.2 ± 4.4 lb They were randomly allotted by body weight to the following treatments: TRT 4 (4 mg NMPA/2.2 lb body weight), TRT 2 (2 mg NMPA/2.2 lb body weight), and CONTROL (0 mg NMPA). On the test day, animals were allowed 30 min. in the stanchions before initial blood sampling. As depicted on the time line in Figure 1, an initial blood sample was obtained at time -15 min. to establish baseline values for catecholamine. At time -5 min., an infusion of either NMPA or placebo was given. At two subsequent 30-sec. intervals, blood samples were obtained to evaluate any rapid catecholamine response. At time 0, LHRH was given and blood samples were obtained up to 90 min. thereafter.

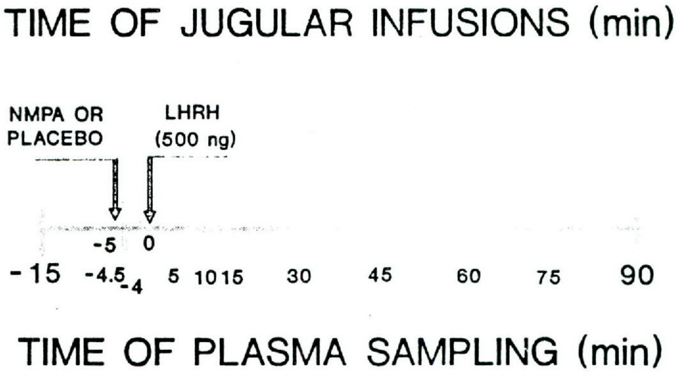

Figure 1. Time line for jugular N-methyl-β-phenetylamine (NMPA) infusions and blood sampling.

Blood samples were immediately processed to yield plasma. Plasma LH samples were stored at -31°F until assay by radioimmunoassay. Plasma catecholamine samples were snap-frozen in liquid nitrogen and stored at -31°F. They were inadvertently allowed to thaw for 48 hours, when there may have been some degradation of catecholamine. Concentrations of catecholamine were analyzed by high-pressure liquid chromatography with electrochemical detection. Statistical analysis was performed by using analysis of variance with the GLM option of SAS (6). Frequency data were analyzed by Chi-square.

Values for the concentrations of LH, AD, and NA are reported as maximum concentration (ng/ml plasma) observed during the sampling period (i.e., peak height), peak amplitude (peak height - baseline), and peak time, the point during a sampling period where a peak was observed.

Results and Discussion

Questions remain about how much guajillo amine is actually ingested during "normal" grazing. Other research currently under way indicates that amines are resistant to degradation in the rumen. At this stage of our research, we feel that jugular infusion is an appropriate way to challenge the animal with these compounds.

Results from the present trial showed that treated wethers had a rapid NA elevation in response to NMPA. In these treated wethers, time to NA peak was less (i.e., more rapid). This is illustrated in the Table 1. Note that the time to NA peak, although not statistically different for the 2-mg dosage, nevertheless appears to be dose-dependent. Proportionally a greater number of wethers had rapid NE peaks (Table 2). No statistically significant differences were detected for AD concentrations, but trends for greater peak height and more rapid peak times were observed in treated versus control animals (Table 3).

Average values for LH peak height, amplitude, and time were not affected by NMPA. Yet, a fewer number of the total treated wethers actually exhibited a response to LHRH (Table 4). This would indicate that NMPA is affecting LH in an "all or none" fashion. The mechanism involved in NMPA's negative effect on the reproductive hormone LH may be associated with a concurrent rise in noradrenaline.

Table 1. Average peak noradrenaline (NA) values.

	TRT 0	TRT 2	TRT4
NA peak ht. (ng)	1.9	1.6	2.1
NA peak time (min.)	34.5[a]	17.8[a,b]	3.6[b]
NA peak amplitude (ng)	1.1	0.99	0.45

Note: [a,b] differ p<0.06.

Table 2. Number of wethers exhibiting noradrenaline (NA) peaks 5 min. post LHRH.

TRT 0 vs. TRT 2		TRT 0 vs. TRT 4	
(2/9)[a]	(5/8)[b]	(2/9)[a]	(5/9)[b]

Note: [a,b] differ p<0.10. Note: [a,b] differ p<0.15.

Table 3. Average peak adrenaline (AD) values.

	TRT 0	TRT 2	TRT 4
AD peak ht. (ng)	5.2	6.6	6.3
AD peak time (min.)	16.6	15.4	11.1
AD peak amplitude (ng)	3.4	4.2	4.6

Table 4. Number of wethers exhibiting luteinizing hormone (LH) peaks 45 min. post luteinizing hormone releasing hormone (LHRH).

TRT 0 vs. TRT 2		TRT 0 vs. TRT 4	
(2/9)[a]	(5/8)[b]	(2/9)[a]	(5/9)[b]

Note: [a,b] differ p<0.06.

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Effects of Exogenous Amines on Reproductive Performance of Female Angora Goats

T.D.A. Forbes, R.D. Randel, D.R. Tolleson, and C.M. Hensarling

Summary

An investigation was conducted into the effects of *N*-methyl-β-phenethylamine (NMPA) and tyramine (T) on corpus luteum function and reproductive performance of Angora goats. Both compounds are widely distributed through the plant kingdom and, because of their sympathomimetic action, may interfere with normal reproductive processes. Seventy-five mature Angora nannies($\bar{x}$ weight = 72 lb live weight, LW) received, by i.v. injection, treatments of either 1.3 or 2.7 mg/lb LW NMPA in 2 ml corn oil; 0.4 or 1.3 mg/lb LW T in physiological saline, or 2 ml corn oil (control), daily for 45 days. Mating was by natural service, beginning after the start of dosing. Jugular blood samples were collected weekly and processed to yield serum. Serum progesterone (P4) concentrations were then determined by RIA. No differences (P = 0.20) were detected between level of dosage within treatment groups in P4 concentration or pregnancy, so groups within compounds were combined before further analysis. Area under the P4 curve of NMPA-treated animals (93 ± 12.9 area units, AU) was lower (P = 0.03) than T-treated (133 ± 11.7 AU) and control animals (132 ± 16.8 AU, P = 0.07).

There was no difference in P4 between T-treated and control animals (P = 0.96). Fewer NMPA-treated goats (64 percent) became pregnant (P = 0.001) than those in either control (92 percent) or T-treated (96 percent) groups. The results show that NMPA, but not T, may interfere with the reproductive performance of goats.

Introduction

Numerous forage and browse plants on rangelands are known to contain phenolic sympathomimetic amines such as phenethylamine, *N*-methyl-β-phenethylamine (NMPA), tyramine (T), hordenine, and *N*-methyltyramine (16,8). While there appears to be no obvious metabolic function for these compounds, they may have considerable importance in preventing insect herbivore (11). It is well established that consumption of *Acacia berlandieri* forage at high levels results in an often fatal locomotor ataxia in sheep and goats called "guajillo wobbles" (12,3). However, as well as the link with guajillo wobbles, NMPA and other phenolic amines such as tyramine may have other less apparent and hence less well-documented effects on animals. Similar compounds have been shown to suppress LH release in ewes (7) and heifers (10) given exogenous GnRH and to alter progesterone production by bovine corpora lutea in-vitro (13). Exogenous sympathomimetic amines act indirectly by releasing biogenic amines (epinephrine, norepinephrine, dopamine) from tissue stores.

In 1988, a drought year, poor reproductive performance (0 percent calf crop) was observed in a group of Braford cattle at the Rio Grande Plains Experimental Ranch in Zavala County, Texas. These animals were consuming 60 to 80 percent of their diet as guajillo (*Acacia berlandieri*) during the 75-day breeding season (J.W. Holloway, pers. comm.). We believed that consumption of high levels of sympathomimetic amines in the forage might have led to continuous secretion of catecholamine, resulting in irregular release of LH and thus a failure to reproduce. An experiment was conducted to investigate the effects of different levels of NMPA and tyramine dosage on progesterone production and pregnancy using Angora goats as a model species.

Experimental Procedures

Seventy five mature Angora nannies were randomly allocated within body weight to one of five treatment groups of 15 animals. Treatments consisted of daily i.v. injection of either a control dose of 2 ml corn oil, 0.4 mg/lb LW tyramine hydrochloride, 1.3 mg/lb LW tyramine hydrochloride, 1.3 mg/lb LW NMPA, or 2.7 mg/lb LW NMPA. Doses for individual animals were based on body weight measured weekly. Tyramine was dissolved in physiological saline, and NMPA was dosed in 2 ml of corn oil because it was immiscible in water. Five days after initiation of treatment, two male goats were placed with the nannies, and mating was by natural service, lasting throughout the 45-day treatment period. The animals were fed coastal bermudagrass hay *ad libitum* and supplemented with approximately 1.0 lb 20 percent commercial goat pellets per animal per day. Pregnancy status was determined by ultrasound after 60 days and confirmed after 90 days.

Before dosing and once a week thereafter, 20 ml of blood were collected by jugular venepuncture from each nanny and processed to yield serum. Serum progesterone (P4) was quantified using validated RIA procedures (18).

Serum P4 concentrations were analyzed by least squares analysis of variance using the GLM procedure of SAS (14). Comparisons between least squares means were made using the PDIFF option. Differences in the number of animals that became pregnant between control and treatment groups were tested by CHI-square tests of independence (17). Where appropriate, actual values of probability (P) are given.

Results and Discussion

Initially, doses of tyramine were set at 1.3 and 2.7 mg/lb LW, but the first two animals dosed at the higher rate died shortly after receiving the first dose, and the remaining animals in the group were dosed at the 0.4-mg/lb level. Though the available evidence (5,9) suggests that the quantities dosed were below toxic levels, four animals treated with NMPA died during the course of the study from unidentified causes, and an additional animal was removed from the study after showing signs of incoordination. One animal in the control group also died. One animal in the control group and three animals in the NMPA-treated group did not have functional corpora lutea based on P4 concentration throughout the study, and therefore were removed from the analyses. No differences (P = 0.20) were detected between doses within compounds in P4 concentration or number of animals that became pregnant, so treatment groups within compounds were combined before further analysis. Tyramine treatment did not reduce serum P4 concentration (P = 0.96) or the number of animals that became pregnant relative to the control animals. The data show that progesterone concentrations in the nannies that produced an active corpus luteum were reduced by treatment with NMPA compared with control (P = 0.07) or T-treated animals (P = 0.03) (Figure 1). The results provide in-vivo support for the findings of Rhodes and Randel (13), who showed that in-vitro P4 production by bovine corpora lutea was depressed when luteal cells were treated with epinephrine, norepinephrine, or dopamine. Fewer NMPA-treated animals became pregnant (14/22) than in the combined control and T-treated animals (38/40) (X^2 = 12.8, P = 0.001).

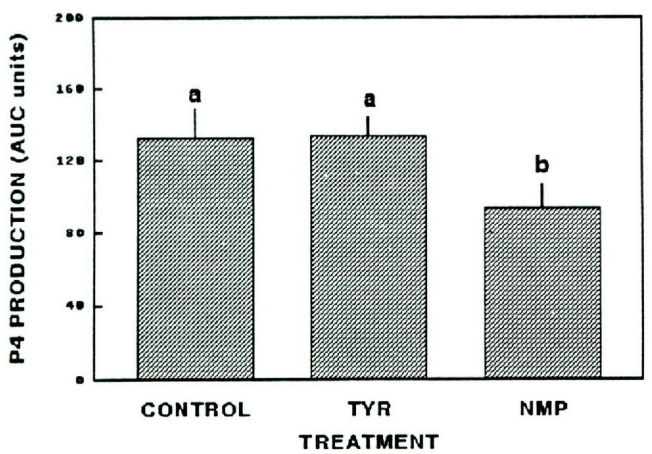

Figure 1. Serum progesterone (P4) production in control, tyramine-treated, or N-methyl-β-phenethylamine (NMP)-treated Angora nannies in 1990 (values are area under the curve, AUC, units).

The study was conducted to determine the potential for these compounds to interfere with reproductive processes under experimental conditions. Lack of any response in serum P4 concentration or numbers of animals conceiving to treatment with NMPA or T would have suggested that these particular compounds were unlikely to affect reproductive performance. A negative response would necessitate further, more intensive, studies to elucidate more precisely the mode of action of the compound(s). The dose levels used in the studies reflected our understanding of the quantities of the amines likely to be consumed, and likely to be degraded in the rumen, based on our own work and that of others (4) and (2). Further studies, however, need to be conducted to determine sites and rates of amine degradation in ruminant animals to determine actual levels of these compounds in the blood supply.

NMPA dosed intravenously at levels above 0.4 mg/lb LW reduced both serum P4 concentrations and the percentage of animals that became pregnant. In contrast, tyramine had no apparent effect on serum P4 concentration or on subsequent conception. These results show that at least one, but not all, exogenous amines have the potential to reduce reproductive performance in Angora goats if introduced into the bloodstream in single pulses in quantities greater than 0.4 mg/lb LW.

Despite the studies carried out on rats (1,6,15,19), there is a paucity of information concerning the impact of exogenous, physiologically active plant compounds on reproduction in any livestock species. Further research is needed to define the mechanisms of allelochemical toxicity on the ability of livestock to detoxify β-phenethylamines and to determine the location(s) of detoxification. The possibility also remains that the progesterone-suppressing activity of sympathomimetic amines such as NMPA may be mediated through mechanisms other than direct effects on the corpus luteum.

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PR-4925

Maternal Recognition of Pregnancy in Sheep and Goats

Fuller W. Bazer and Troy L. Ott

Summary

During the estrous cycle, the life-span of the ovarian corpus luteum is limited because progesterone down-regulates its own receptors in the uterus, which allows uterine receptors for estrogen and oxytocin to increase. Oxytocin from the corpus luteum and/or posterior pituitary then stimulates uterine secretion of luteolytic pulses of prostaglandin $F_{2\alpha}$ (PGF) as shown in Figure 1. During pregnancy, however, the conceptus (embryo and associated membranes) secretes Type I trophoblast interferon (tIFN), which stabilizes the progesterone receptors and, directly or indirectly, prevents up-regulation of uterine receptors for estrogen and oxytocin. Consequently, the uterine endometrium is unable to secrete luteolytic pulses of PGF (Figure 2) and pregnancy can be established. Secondary antiluteolytic signals from the conceptus after about day 25 of pregnancy may include tIFN and/or lactogenic hormones, e.g., placental lactogen, which continue to stabilize and/or up-regulate endometrial progesterone receptors and/or suppress estrogen and oxytocin receptors to prevent uterine release of PGF and ensure maintenance of pregnancy.

Introduction

Maternal recognition of pregnancy results from signalling between the conceptus (embryo and its associated membranes) and the maternal system (1). These signals ensure maintenance of structural and functional integrity of the corpus luteum (CL) on the ovary, which would otherwise regress at the end of the estrous cycle. The CL produces progesterone, the hormone of pregnancy, which is required to stimulate and maintain uterine functions necessary for embryonic development, implantation, placental formation, and successful fetal/placental development to the end of gestation.

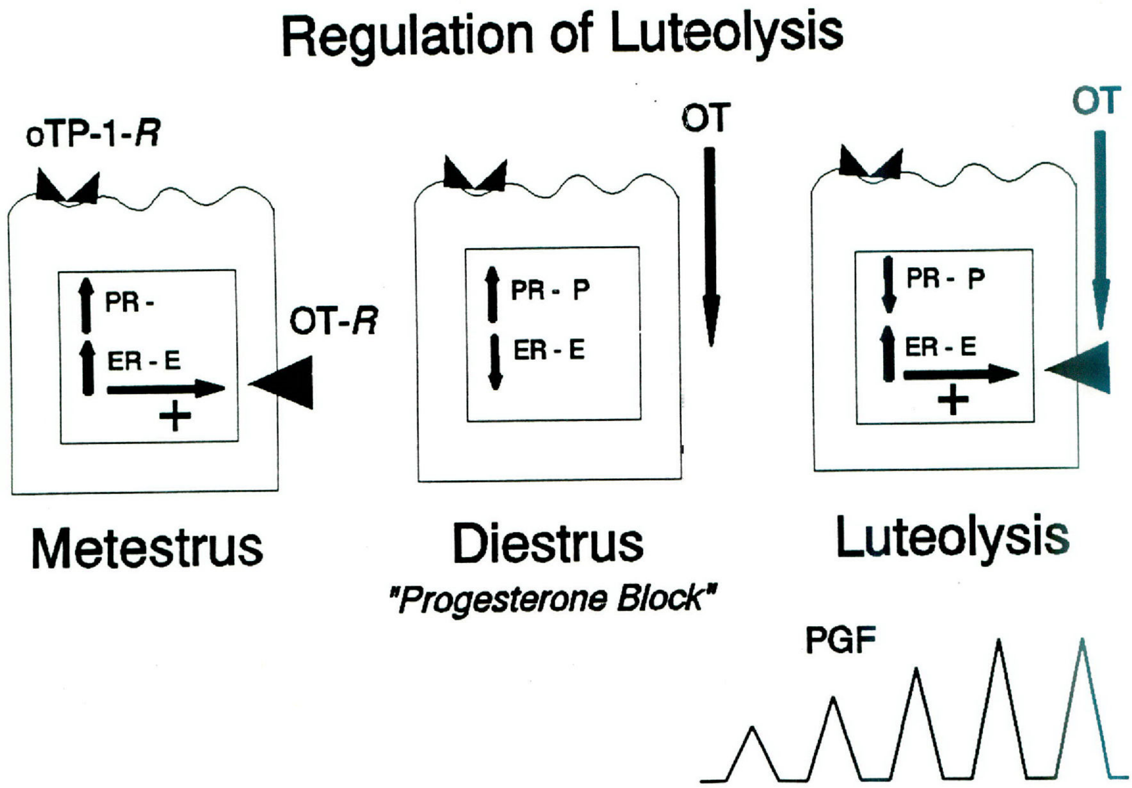

Figure 1. The current model for cyclic ewes assumes that oxytocin receptors are present on uterine epithelium during metestrus because occupied estrogen receptors are present. Endometrial progesterone receptors are also present, but low circulating levels of progesterone result in insufficient numbers of occupied progesterone receptors to suppress synthesis of oxytocin receptors. During diestrus, endometrial estrogen receptors and estradiol in plasma are low. Occupied progesterone receptors initiate and maintain the "progesterone block" to synthesis of receptors for estrogen and oxytocin for 10 to 12 days. During late diestrus, progesterone down-regulates progesterone receptors to allow up-regulation of receptors for estrogen and oxytocin, an event facilitated by increasing rates of estradiol secretion by ovarian follicles. Pulsatile release of oxytocin from CL and posterior pituitary induces release of luteolytic pulses of PGF from the endometrium to destroy the CL.

The terms luteal protective, antiluteolytic, and luteolytic must be defined. Prostaglandin $F_{2\alpha}$ (PGF) is the luteolytic hormone from the uterus, which causes structural and functional regression of CL in livestock. Luteal protective signals, e.g., PGE_2 (PGE), may antagonize potential luteolytic effects of PGF to protect the CL, but there is no good evidence that PGE alone is responsible for maintenance of CL. In sheep and goats, the conceptus signals responsible for maternal recognition of pregnancy act on the uterus to prevent uterine release of luteolytic pulses of PGF, but do not act directly on the CL. The antiluteolytic signals produced by conceptuses of sheep and goats during early pregnancy are called Type I trophoblast interferons (tIFNs).

Hormonal Requirements for Luteolysis

Sheep and goats have estrous cycles of about 17 and 20 days, respectively. An ovulatory surge of luteinizing hormone (LH) from the anterior pituitary gland occurs near the time of onset of estrus, when the female first accepts the male for mating. The ovulatory surge of LH initiates events that culminate in ovulation about 30 hours later. With maturation of the CL, concentrations of progesterone in peripheral blood are highest around day 12 of the cycle and, in cyclic females, luteolysis is induced by pulsatile release of PGF from the uterus on days 15 to 16. The antiluteolytic signals for maternal recognition of pregnancy in sheep and goats are tIFNs, which act on the uterus to prevent production of luteolytic pulses of PGF.

Three hormones from the ovary are known to influence endometrial production of luteolytic pulses of PGF. These are progesterone from the CL, estrogen from ovarian follicles, and oxytocin from CL and posterior pituitary gland. A number of mechanisms associated with endocrine regulation of luteolysis are understood in sheep and goats. Endometria of ewes are stimulated by progesterone to increase levels of a fatty acid called arachidonic acid, which is converted to PGF

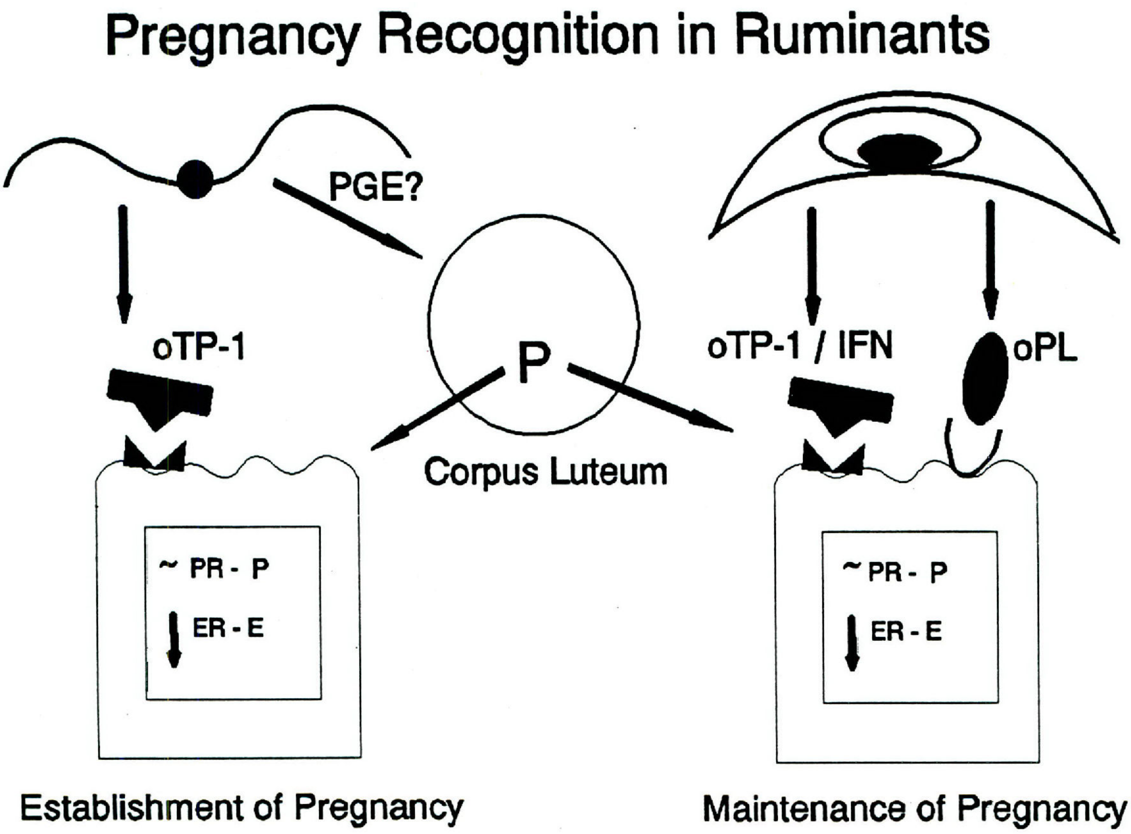

Figure 2. The model currently being tested assumes that Type I trophoblast interferons, e.g., otIFN, are primary antiluteolytic paracrine hormones, which act on endometrial epithelium to stabilize progesterone receptors and inhibit synthesis of estrogen receptors. Consequently, synthesis of endometrial oxytocin receptors is inhibited. For maintenance of pregnancy beyond days 25 to 30, there is a secondary period of secretion of immunoreactive and bioactive otIFN-like protein, which may be reinforced by effects of placental lactogen to stabilize endometrial progesterone receptors, as well as inhibit synthesis of estrogen receptors. The paracrine effects of otIFN and/or placental lactogen prevent uterine secretion of luteolytic PGF, which might otherwise cause luteolysis and termination of pregnancy. Endometrial sensitivity to oxytocin-induced and estrogen-induced secretion of PGF does occur between days 25 and 30 of pregnancy in ewes.

when the uterus is stimulated by estrogen and oxytocin (2).

Oxytocin secreted by the CL and posterior pituitary gland stimulates pulsatile uterine release of PGF required for luteolysis. Oxytocin in synthesized in high amounts in ovarian follicles and CL of ewes, cows, and goats between day 0 (estrus) and day 7 after onset of estrus (3,4,5,6,7). Oxytocin is then stored in the CL until it is released into ovarian vein blood during luteolysis (8,9). Oxytocin from the CL and posterior pituitary binds to special receptors on the uterine lining (endometrium) to stimulate release of luteolytic pulses of PGF (10). In sheep (10) and cows (11,12,13,14), endometrial receptors for oxytocin are low or undetectable until just before the luteolytic period and then increase rapidly during the lutolytic period, i.e., days 14 and 16 (sheep) or days 17 and 20 (goats, cows) to allow oxytocin to stimulate pulsatile release of PGF.

During the estrous cycle, progesterone from the CL inhibits synthesis of oxytocin receptors by endometrial epithelium for 10 to 12 days; a period referred to as the "progesterone-block" (15). Afterwards, endometrial receptors for oxytocin increase because progesterone inactivates its own receptors after about day 12 of the cycle to end the "progesterone-block." The decrease in endometrial progesterone receptors is followed by an increase in endometrial receptors for estrogen and oxytocin (11). This up-regulation of estrogen and oxytocin receptors results in initiation of endometrial release of luteolytic pulses of PGF, which destroys the CL, and the female begins a new estrous cycle.

During the luteolytic period, about 98 percent of the PGF pulses are associated with a pulse of oxytocin (16,17). Further, treatment of ewes (18) or goats (19) with an oxytocin antagonist, to prevent binding of oxytocin to its uterine receptors, with passive or active immunization of ewes against oxytocin (20,21) or with continuous infusion of oxytocin to suppress oxytocin receptors (22) prevents or significantly delays luteolysis. These results indicate a central role for oxytocin in the luteolytic mechanism, which is dependent upon uterine release of about five pulses of PGF per 25 hours for complete regression of the CL (23). Low-amplitude pulses of PGF from the uterus act on CL to cause release of oxytocin, which then acts on the uterus to induce a pulse of uterine PGF (10). This mechanism is repeated at 4- to 5-hour intervals between days 14 and 17 or until the CL is depleted of its limited stores of oxytocin.

Other mechanisms to explain the episodic release of oxytocin and PGF have been proposed because release of oxytocin from the CL, even when there is one CL on each ovary, and the posterior pituitary are synchronous in sheep (16). Control of oxytocin release by hormones other than PGF or PGE is possible, but such factors have not been identified.

Pregnancy Recognition in Sheep

The presence of a normal conceptus in the uterus prevents luteolysis because tIFNs are antiluteolytic signal(s) produced by the conceptus which prevent uterine production of luteolytic pulses of PGF. The tIFNs may prevent luteolysis by (1) stabilization of endometrial progesterone receptor to extend the "progesterone block" and prevent increases in endometrial synthesis of oxytocin and estrogen receptors; (2) direct inhibition of estrogen receptors to prevent pulsatile release of PGF required for luteolysis; or (3) direct inhibition of synthesis of endometrial oxytocin receptors (24). Available results indicate that endometrial epithelium of pregnant ewes, cows, and goats have few or no receptors for either oxytocin (24) or estrogen (25).

Pregnant ewes fail to experience luteolysis in response to doses of injected oxytocin (26) and estradiol (26,27,28) that cause luteolysis in cyclic ewes and cows (29). There is no evidence for differences in the pattern of release of oxytocin between cyclic and pregnant ewes (9,16,30) between days 13 and 16 after estrus. However, a consistent finding has been that uterine oxytocin receptor numbers are very low or absent in pregnant ewes (10,15). Therefore, pulsatile release of PGF required for luteolysis is abolished during pregnancy (15,16,31).

Homogenates of sheep conceptuses were first shown to extend CL life span in ewes when infused into the uterine lumen but not the utero-ovarian venous drainage (32,33,34). Sheep conceptus homogenates do not contain either chorionic gonadotrophin- or prolactin-like hormones (35). To identify the antiluteolytic factor, sheep conceptuses were cultured in vitro in the presence of radiolabelled amino acids, and radiolabelled proteins released into the culture medium were identified. The first major protein secreted by the membranes of the conceptus (trophoblast) was identified as ovine trophoblast protein-1 (oTP-1, see 24), now called ovine Type I trophoblast interferon (otIFN).

The otIFN is secreted between days 10 and 21 of pregnancy, has a molecular weight of 19,000, and binds to endometrial receptors (24). There is a second period of secretion of immunoreactive and bioactive otIFN-like protein by chorion (derived from trophoblast) between days 25 and 45 of pregnancy (36). Infusion of otIFN (37) or recombinant otIFN (rotIFN, 38,39) into the uterine lumen from days 12 to 14 extends the interestrous interval and CL lifespan, indicating that otIFN alone is the antiluteolytic factor produced by sheep conceptuses. The action of otIFN appears to be directly on the endometrium because no evidence exists that it is transported from the uterus to the CL (40).

Endometria taken on day 15 of the estrous cycle when high levels of oxytocin receptors are present indicate that otIFN does not prevent binding of oxytocin to its receptor or inhibit oxytocin stimulation of secretion of PGF (41). Therefore, the antiluteolytic effect of otIFN must be to prevent development of the luteolytic mechanism, that is, to block estrogen and oxytocin receptor synthesis. Secretion of otIFN (ng/uterine flushing) begins on about day 10 (42) and increases rapidly as sheep conceptuses change in their shape from spherical (312 ng), to tubular (1,380 ng), to filamentous (4,455 ng) forms on days 12 to 13 (43). Successful transfer of embryos to cyclic ewes can be accomplished only as late as day 12, i.e., 48 to 72 hours before the luteolytic period. This suggests that otIFN is secreted before the luteolytic period to directly or indirectly inhibit endometrial synthesis of estrogen and oxytocin receptors to prevent uterine release of luteolytic pulses of PGF.

Functional endometrial receptors for oxytocin are present in low or undetectable numbers in pregnant ewes when measured directly (10,15) or indirectly (45,46). Uterine secretion of PGF (37,44) in response to oxytocin is also reduced significantly when endometria of cyclic ewes are exposed to otIFN on days 12 through 14, which indicates the absence of functional endometrial receptors for oxytocin when ewes are treated with otIFN. Intra-uterine infusion of otIFN between days 11 and 15 of the estrous cycle reduces numbers of oxytocin receptors, the affinity of the oxytocin receptors for oxytocin and endometrial estrogen receptors; however, effects of otIFN on endometrial receptors for progesterone are not yet understood (46).

The otIFN may inhibit synthesis of oxytocin receptors and reduce their affinity for oxytocin, perhaps by suppressing synthesis of endometrial estrogen receptors and/or stabilizing endometrial progesterone receptors. A rapid increase in endometrial receptors for estrogen occurs in ewes following withdrawal of progesterone (47), which suggests that failure of endometrial estrogen receptors to increase during pregnancy is associated with either stabilization of progesterone receptors by otIFN or direct inhibition of estrogen receptor synthesis by otIFN. During pregnancy, endometrial estrogen receptors are significantly lower for pregnant than for cyclic ewes on day 16 (71; T.L. Ott, T.P. Ogle and F.W. Bazer, unpublished results) and for cyclic ewes on day 16 after receiving intrauterine infusions of otIFN on days 11 to 15 and (M.A. Mirando, T.P. Ogle, J.P. Harney, T.L. Ott, and F.W. Bazer, unpublished results). In addition, estrogen receptors in endometrial surface and superficial glandular epithelia are essentially absent in day 15 pregnant ewes (25).

Temporal changes in endometrial receptors for progesterone during the estrous cycle and early pregnancy of sheep have not been reported previously. However, unpublished results (T.L. Ott, T.P. Ogle, and F.W. Bazer) indicate that (1) endometrial progesterone receptors are lower on days 12 and 14 than days 10 and 16 of the estrous cycle; (2) endometrial progesterone receptors do not change significantly between days 10 and 16 of pregnancy, indicative of stabilization of progesterone receptors; and (3) estrogen receptors are much lower, compared with progesterone receptors in pregnant ewes. Intrauterine infusion of otIFN increased endometrial progesterone receptors about 40 percent when endometrium was taken before the concentrations of progesterone in plasma declined and the estrogen receptors increased (M.A. Mirando, R.J. Moffatt, T.L. Ott, and F.W. Bazer, unpublished results). However, there was no detectable effect of otIFN if the endometrium was taken after plasma progesterone had declined and estrogen receptors had increased (M.A. Mirando, T.L. Ott, T.P. Ogle, and F.W. Bazer, unpublished results). In sheep, the antiluteolytic effects of otIFN are dependent on the presence of progesterone from the CL (48).

The mediator of maternal recognition of pregnancy in sheep is otIFN, which acts as an antiluteolytic signal to prevent uterine secretion of luteolytic pulses of PGF. Our current working hypothesis is that otIFN stabilizes endometrial progesterone receptors and down-regulates endometrial estrogen receptors, which prevents synthesis of endometrial receptors for oxytocin. Failure of pregnant ewes to respond to the potential luteolytic effects of estradiol and oxytocin are presumably due to the absence of receptors for each of these hormones.

Pregnancy Recognition in Goats

Goat conceptuses exert an antiluteolytic effect similar to that of sheep conceptuses (24). Goat conceptuses survive and extend luteal function when transferred to ewes (49), and goat conceptuses secrete proteins with biochemical characteristics similar to those of otIFN (50). The uterine luteolysin in goats is PGF, and the conceptus interferes with oxytocin-induced pulsatile release of PGF as described for ewes (51). Removal of goat conceptuses from the uterine lumen between days 13 and 15 does not affect length of the estrous cycle, but removal of the conceptus on day 17 extends lifespan of the CL and, therefore, the cycle by 7 to 10 days (50).

This suggests that maternal recognition of pregnancy in goats occurs around day 17. Goat conceptuses secrete caprine trophoblast protein-1 (cTP-1) between days 16 and 21 that can be immunoprecipitated with antiserum to otIFN; therefore, cTP-1 may be the antiluteolytic protein in goats with properties similar if not identical to those of otIFN (50). Pulsatile release of oxytocin and PGF are suppressed in pregnant compared with cyclic goats between days 10 to 12 and estrus or day 20 of pregnancy (51), suggesting that antiluteolytic mechanisms in the goat are similar to those for sheep and cows.

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Type I Conceptus Interferons: Maternal Recognition of Pregnancy Signals and Potential Therapeutic Agents

Fuller W. Bazer and Troy L. Ott

Summary

Type I trophoblast interferons of sheep, goats, and cows are biochemical signals for maternal recognition of pregnancy, which may be useful for enhancing fertility in animal agriculture and may have therapeutic value in human and veterinary medicine. The Type I conceptus interferons share antiviral, anticellular, and immunosuppressive properties with Type I interferons from leukocytes, but lack their cytotoxic effects. Goats and sheep infected with caprine arthritis-encephalitis virus (CAEV) and ovine progressive pneumonia virus (OPPV), respectively, may benefit from the therapeutic antiviral properties of Type I trophoblast interferons.

Introduction

Establishment of pregnancy requires that the conceptus (embryo and its associated membranes [trophoblast]) secrete biochemical signals (e.g., steroids, proteins or prostaglandins) that affect the corpus luteum (CL) directly as a luteotrophic signal (e.g., human chorionic gonadotrophin), as a luteal protective signal (e.g., prostaglandin [PG] E_2) or indirectly as an antiluteolytic signal that inhibits uterine production of luteolytic amounts of $PGF_{2\alpha}$ (PGF). These signals ensure maintenance of corpus luteum function and establishment of pregnancy. Type I trophoblast interferons (tIFN) secreted by sheep, goat, and cow conceptuses are the antiluteolytic signals responsible for maternal recognition of pregnancy because they act locally on the uterine endometrium to suppress release of luteolytic amounts of PGF (1).

The tIFNs have high amino acid sequence homology with both interferon alpha I ($IFN_{\alpha I}$) and interferon alpha II ($IFN_{\alpha II}$) or omega interferon (IFNΩ), which are produced by white blood cells (2,3,4). The tIFNs produced by sheep, cow, and goat are very similar in structure and biological activity (1). Mechanisms involved in maternal recognition of pregnancy are similar for sheep, cow, and goat, but are best described for sheep. Therefore, this paper will briefly discuss the role of ovine tIFN (otIFN) in the establishment of pregnancy in sheep and then focus on the potential therapeutic value of tIFNs in human and veterinary medicine.

Ovine tIFN is the major protein secreted by sheep conceptuses between days 12 and 21 of gestation that has antiluteolytic activity and is responsible for the establishment of pregnancy. Secretion of otIFN begins between days 8 and 10 and increases rapidly (ng/uterine flushing) as conceptuses change from spherical (312 ng) to tubular (1,380 ng) to filamentous forms (4,455 ng) on day 13 (5). Maximum secretion (100,000 to 150,000 ng/24 hours) occurs between days 14 and 16 of pregnancy (6).

Maternal Recognition of Pregnancy

The uterine endometrium of cyclic ewes releases luteolytic pulses of PGF on Days 15 and 16, which cause structural and functional demise of the CL(1). In ewes that have been mated and have normal conceptuses developing in the uterine lumen, endometrial release of luteolytic pulses of PGF are suppressed, and the corpus luteum on the ovary remains functional and continues to produce progesterone (1). Intrauterine injections of otIFN alone at 7:30 a.m. and 5:30 p.m. on days 12 through 14 suppress uterine release of luteolytic pulses of PGF. Corpus luteum lifespan in these cyclic ewes is extended from about 19 days to 28 days. Using recombinant otIFN (rotIFN) alone, we confirmed that otIFN is the only antiluteolytic protein secreted by sheep conceptuses (7,8).

Therapeutic Value of Trophoblast Interferons

The tIFNs have potential therapeutic value because they are interferons that inhibit cellular proliferation (9), exert antiviral effects (10), and suppress the immune system (11). Evaluation of the potential therapeutic value of tIFNs requires sufficient amounts for clinical studies. To accomplish this, a synthetic gene for otIFN was produced and is being used in yeast and bacterial expression systems to produce rotIFN that is identical to natural otIFN in terms of its structure and biological activities. Native otIFN and rotIFN have 0.7-2 x 10^8 antiviral units/mg protein(8). The antiviral activity of otIFN is as potent as that of known recombinant leukocyte interferons from humans (rhIFN) and cattle (rbIFN), but otIFN does not exert cytotoxic effects characteristic of treatment with rhIFNα and rbIFNα (9,12). Exposure of human and feline peripheral lymphocytes infected with human immunodeficiency virus (HIV) and feline (cat) immunodeficiency virus (FIV), respectively, to otIFN inhibited replication of the viruses but did not exert cytotoxic effects on the infected cells when used at concentrations up to 200,000 antiviral units/ml. However, rbIFNα and rbIFNα exerted significant cytotoxic effects at only 1,000 to 5,000 antiviral units/ml.

The tIFNs also have anticellular activity that is equivalent to or greater than that of rbIFNα and rhIFNα (9), as measured by its ability to prevent cells from dividing, and may be useful in the treatment of cancers. When anticellular activities of otIFN, rbIFNα, and rhIFNα were compared using human amnion (WISH) and Madin-Darby bovine kidney (MDBK) cells, all inhibited proliferation of the cells. The otIFN was more effective at lower dosages and, at high dosages (50,000 antiviral units/ml of oTP-1), more effectively blocked cell proliferation without adverse effects on cell viability. At the same concentrations of antiviral activity, rbIFN caused substantial cell death (9,12).

Human patients having steroid-dependent mammary tumors respond to treatment with beta interferons because of increased receptors for progesterone and decreased receptors for estrogen in tumor cells (13).The otIFN stabilizes receptors for progesterone while decreasing receptors for estrogen in cells of the uterine endometrium (T.L. Ott, P.J. Harney, T. Ogle, and F.W. Bazer, unpublished results). The health of many women is affected adversely by estrogen-dependent tumors of the mammary glands and reproductive tract. Because estrogen-dependent tumor growth depends on the presence of cellular receptors for estrogen, tIFNs have potential therapeutic value because they inhibit synthesis of cellular receptors for estrogen, which should prevent estrogen-dependent growth of the tumors.

Humans suffering from infection with HIV or diseases such as hairy cell leukemia are willing to consider life-long therapy with rhIFN; however, chronic treatment with rhIFN results in development of resistance to the effects of currently available recombinant rhIFN (14). In addition, high doses of rhIFN produce intolerable fever and chills, anorexia, weight loss, and fatigue (15) and may also cause seizures (16). Interferons have both immunoenhancing and cytotoxic effects; therefore, therapeutic doses are chosen that favor the immunoenhancing effects. The tIFNs act through receptors on the uterine epithelium that are in direct contact with the conceptus and are exposed to as much as 40 million units of antiviral activity per 24 hours without cytotoxic effects. A gene for human tIFN (htIFN) that has 85 to 87 percent homology with otIFN has been cloned from a human placental DNA library (17). These tIFNs have unique "cell friendly" properties, which are likely to make them especially desirable therapeutic agents for use in animal agriculture, veterinary medicine, and human medicine.

A number of diseases affecting livestock result from infections by lentiviruses of the family Retroviridae. These include, ovine progressive pneumonia virus (OPPV), caprine arthritis-encephalitis virus (CAEV), bovine immunodeficiency-like virus (BIV), equine infectious anemia (EIA), and feline immunodeficiency virus (FIV) and simian immunodeficiency virus (SIV) (18). Diseases caused by OPPV, CAEV, and BIV for example, are uniquely suited for testing the therapeutic value of oTP-1 in the control of lentivirus-induced diseases because conceptuses of each of these species secrete tIFN. These animal models will be studied to assess the therapeutic value of tIFNs in preventing or ameliorating vertical transmission (i.e., via the placenta) and horizontal transmission (i.e., animal to animal) of these viruses, as well as the efficacy of tIFNs in treating infected fetuses and adult sheep, goats, and cattle.

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PR-4927

Use of Ultrasound Technology for Pregnancy Diagnosis and Fetal Number Determinations in Fine-Wool Sheep

T. Willingham, M. Shelton, P. Thompson, and K. Bretzlaff

Summary

In the fall of 1990, five ultrasound machines were used to evaluate current ultrasound technology. A total of 1,191 scans were made on Rambouillet ewes to diagnose pregnancy and determine fetal numbers. Accuracy of pregnancy diagnosis based on lambing results ranged from 92.8 to 97.6 percent with a mean of 94.9 percent. The error in pregnancy diagnosis may largely be explained by fetal losses during gestation. Accuracy of fetal number determinations ranged from 78.8 to 90.6 percent with a mean of 85.6 percent.

Scanning after 30 days of gestation was found to improve accuracy of both pregnancy and fetal numbers determination, with a range of day 40 to 60 post-breeding being more desirable. Fetal number determinations were more accurate (87.8 percent) among single-bearing ewes as opposed to multiple-bearing ewes (78.7 percent).

The results of this study indicate that ultrasound technology can be used effectively for pregnancy diagnosis, but fetal number determination proved less accurate. Technician and machine differences were not evaluated as the two factors were confounded in this particular trial; however past experience indicates technician skill has a significant impact on accuracy.

Introduction

In recent years interest in detection of pregnancy in sheep has increased. Early detection of pregnancy would allow a producer to cull or manage nonpregnant animals differently from those diagnosed as pregnant, thus offering potential savings in feed and labor cost. Although several methods of pregnancy detection are available, the cost, accuracy, or stage of pregnancy at which they may be applied has limited their use in practice. In addition, recent technology (the use of ultrasound) has been developed that allows for the determination of fetal numbers, which would allow for greater management options and perhaps for some use in selection as well.

Determination of fetal numbers would allow a producer to manage single-bearing ewes differently from multiple-bearing ewes. This practice would permit more efficient use of feed resources, possible improvement in survival of multiple birth lambs, and improved use of labor and facilities. However, the cost of using ultrasound imaging may be prohibitive or unwarranted if accuracies of pregnancy diagnosis and fetal number determinations are low or if the information is not actually used to improve productivity or efficiency. This study was conducted to evaluate the current status of ultrasound imaging and/or to determine the improvement in this technology since an earlier study (1).

Experimental Procedure

In the fall of 1990, at the Winters ranch lease near Brady, Texas, 778 fine-wool ewes were scanned from one to four times using different ultrasonic devices. Ultrasound equipment consisted of a Tokio Keiki with either a 7.5-MHz rectal transducer or a 5-MHz abdominal probe, Avionics OTE 8300 with a 3.5-MHz abdominal transducer, Bion Equiscan with a 3 MHz abdominal transducer, and an Ausonic Sona Vet 1 with a 5-MHz abdominal transducer. Each type of machine was operated by a different technician; however, a single technician operated the Tokio Keiki with the external and rectal transducer. Data collected included date of scanning, device used, fetal numbers, lambing date, and number of lambs born. Because some ewes were scanned more than once, a total of 1,191 scans were made. Ewes lost or missing before lambing were excluded from this number and from analysis.

Chi-square analysis was used to evaluate machine or operator differences in pregnancy diagnosis and fetal number determinations. However because machine and operator were confounded, separation of these two variables was not possible. Determination of fetal age at scanning was done by the following equation:

150 day gestation - (lambing date - scan date).

Results and Discussion

The accuracies of diagnosis of pregnancy and fetal numbers are given in Table 1. From Chi-square analysis, a statistical difference ($P<0.001$) in machines/operator was found for fetal number determination but not for pregnancy diagnosis. Though variation is evident between machines, it is not clear that the difference is due to that particular machine, since different technicians operated each model, thus confounding machine and technician error. It was not the purpose of this study to compare machines but to evaluate the usefulness of ultrasound technology for pregnancy detection and fetal number determination. It appears that the only statement that can be made relative to equipment is that under the conditions of this study, the rectal probe appeared to be less satisfactory for determination of fetal numbers. The operator believed that this was due to some of the animals' being past 60 days of gestation at examination and that the accuracies would have been better when considering only animals in early (30 to 60 days) gestation.

Table 1. Accuracy of pregnancy diagnosis and fetal number determination by machine.[a]

Machine/probe	n	Pregnancy diag. Number correct scans	Pregnancy diag. Accuracy (%)	Fetal numbers Number correct scans	Fetal numbers Accuracy (%)
Tokio Keiki 7.5 MHz Rectal	189	177	93.6	149	78.8
Tokio Keiki 5 MHz External	223	213	95.5	187	83.9
Avionics OTE 8300 3.5 MHz External	502	479	95.4	455	90.6
Bion Equiscan 3 MHz External	82	80	97.6	74	90.2
Ausonic Sona Vet 1 5 MHz External	195	181	92.8	156	80.0
Overall	1191	1130	94.9	1020	85.6

[a]Chi-square indicates a difference but does not provide multiple comparison.

Accuracy of pregnancy diagnosis (based on lambing results) ranged from a low of 92.8 percent to a high of 97.6 percent with an overall accuracy of 94.9 percent. Accuracy of fetal number determination (based on lambing results) ranged from 78.8 percent to 90.6 percent with the overall accuracy of 85.6 percent. Mistakes or perceived errors may occur from erroneous scans, abortion, resorption of the fetus, scanning too early in gestation, or mispairing of lambs at birth.

Table 2 displays the location of errors made in pregnancy diagnosis. The error rate of 5.1 percent (the reciprocal of 94.9 percent accuracy) in pregnancy diagnosis shown in Table 1, included 10 animals (0.84 percent of all scans) being diagnosed as open, which lambed. One possible explanation for this type of misdiagnosis, which

Table 2. Frequency distribution of pregnancy diagnosis by actual classification determined at lambing.

Ultrasound determination	Number/ percent	Actual Nonpregnant	Actual Pregnant	Total
Nonpregnant	n	87	10	97
	% of total	7.30	0.84	8.14
	% of group	89.69	10.31	100.00
Pregnant	n	51	1043	1094
	% of total	4.28	87.57	91.85
	% of group	4.66	95.34	100.00
Total	n	138	1053	1191
	%	11.58	88.41	99.99

will be discussed later, is stage of gestation at time of scanning. Of the 10 pregnant ewes diagnosed as open, 6 were scanned before day 41 of gestation. In addition, 51 animals (4.28 percent) were diagnosed as pregnant, yet failed to lamb (Table 2). Prior research (2) has shown that in the absence of known infectious disease problems, 4.1 percent of a potential lamb crop may be lost between conception and parturition in an average year. Thus, an occurrence of 4.3 percent open animals previously diagnosed as pregnant could be largely explained by fetal losses. This suggests that an expectation of 100 percent agreement between pregnancy diagnosis and actual lambing rates is unrealistic. Therefore, in highly fertile flocks in which only a small percentage of ewes are identified as open and some of the ewes that will ultimately fail to lamb cannot be identified due to fetal resorption, the use of ultrasound for pregnancy diagnosis may not offer practical advantages. On the other hand, ultrasound would be much more valuable with problem flocks or under conditions in which a higher percentage is expected to be open.

A second use of ultrasound is the determination of fetal numbers. This component may allow an individual to separate the flock into management groups for better utilization of feed, labor, and facilities or to select animals according to expected types of birth where lambing records are impractical. The accuracy of fetal number determination is shown in Table 3. Values shown in bold print indicate correct diagnosis with the overall accuracy being 85.6 percent.

Those numbers not in bold print indicate an error in either diagnosing fewer lambs than actually born (as 0.59 + 0.25 + 4.62 = 5.46 percent) or more lambs than

Table 3. Distributon of fetal numbers determined by ultrasound compared with number of lambs born

Ultrasound determination		Birth type: Open	Single	Multiple	Total
Open	n	**87**	7	3	97
	% of total	**7.30**	0.59	0.25	8.14
	% of group	**89.69**	7.22	3.04	100.00
Single	n	41	**692**	55	788
	% of total	3.44	**58.10**	4.62	66.16
	% of group	0.44	**87.82**	6.98	100.00
Multiple	n	10	55	**241**	306
	% of total	0.84	4.62	**20.24**	25.70
	% of group	3.27	17.97	**78.76**	100.00
Total	n	138	754	299	1191
	% of total	11.58	63.31	25.11	100.00

actually born (3.44 + 0.84 + 4.62 = 8.90 percent). The 5.46 percent figure can only represent an error in scanning, an error in data collection, or scanning too early in gestation; however, the 8.90 percent figure can represent both errors in scanning or fetal loss. Since the latter figure is larger, it almost certainly includes fetal losses. The difference between these figures is 3.44, and as mentioned elsewhere in the paper, one study suggests a 4.1 percent loss. These two figures appear to be comparable. However, identifying the causes of these two types of errors proves difficult. Potential problems common to both are technician error or scanning outside an optimum period in gestation, while fetal losses after scanning would cause an overestimate of lamb numbers. Although the accuracy of fetal number determination (85.6 percent) may be less than desirable, the author feels that any adverse impact on management decisions based on fetal numbers would be minimal at this level of accuracy. If open ewes were to be sold after scanning, less than 1 percent of the flock would be sold erroneously, while 4.3 percent of the flock maintained as bred would not lamb. Markedly reducing the number of ewes diagnosed as single or multiple bearing that subsequently fail to lamb will prove difficult because of the high probability that some fetal losses will occur. However, attempting to scan at an optimal stage in gestation may reduce errors in both over estimating and underestimating of lamb numbers.

Stage of gestation does have an impact on the accuracies of both pregnancy diagnosis and fetal number determination (Table 4).

These results indicate an increase of accuracy of pregnancy diagnosis with an increase in fetal age. This does not appear to be true in the case of determination of fetal numbers. There is no indication of improvement in accuracy beyond 50 days, and there is good reason to believe that accuracy decreases at advanced fetal age. In this study the sample size beyond 70 days was small. Past research (1) conducted at this center has shown a decline in accuracy of fetal number determination after 70 days.

Table 4. Accuracy of pregnancy and fetal number determinations as affected by stage of gestation.

Stage of gestation when scanned (days)	n	Pregnancy diagnosis: Number correct	Pregnancy diagnosis: Accuracy (%)	Fetal numbr determination: Number correct	Fetal numbr determination: Accuracy (%)
0-30	12	9	75.0	8	66.7
31-40	56	53	94.6	49	87.5
41-50	156	154	98.7	140	89.7
51-60	403	401	99.5	360	89.3
61-70	187	187	100.0	155	82.9
71-80	39	39	100.0	33	84.6
80-119	21	21	100.0	19	90.5

Results from this current trial indicate an optimal scanning time at 41 to 60 days gestation for fetal number determination, although a wider range may prove acceptable to an individual producer.

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PR-4928

How Do Angora Goats Respond Reproductively to Different Levels of Protein in Feed?

N.E. Garza, Jr., C.A. Taylor, Jr., J.E. Huston, and R.A. Moen

Summary

A study was conducted to determine the influence of body condition before breeding and of protein level in feed on the reproductive rate of adult Angora nannies. To establish high and low body conditions before breeding, the two groups were put into separate but similar rangeland pastures. One group was fed a 16 percent protein ration free choice; the other was not. After 41 days the two groups differed significantly in body weight and condition (High, Low). These two groups were then divided into three protein levels each (17, 13.5, and 10 percent). The six groups, High 17, High 13.5, High 10, Low 17, Low 13.5, and Low 10, were kept in confinement and fed free choice for 14 days before breeding and for 37 days of a 51-day breeding season. After day 37, the nannies were fed the same 16 percent ration at 2.5 percent of their body weight per day for 50 days. Approximately 31 days before kidding, the nannies were put into a small pasture and fed a 16 percent ration free choice. Nannies were kidded in small pens to record accurately birth data. Kidding rate of High condition females was not affected by protein in the ration, whereas Low condition females appeared to respond negatively to the low protein ration (non-significant trend).

Results indicate that goats in High body condition before breeding were little affected by protein levels in the feed. Likewise, goats in Low body condition before breeding received adequate nutrition from 17 and 13.5 percent protein diets. Goats in the Low 10 group before breeding had reduced intake and tended to have lower reproductive rates. These results indicate the importance of assessing the nutritional status of Angora females before breeding and suggest that a high-protein diet during breeding will improve the reproductive rate of undernourished nannies.

Introduction

The Edwards Plateau, a semi-arid region of Texas with highly variable rainfall distribution, is covered with diverse vegetation suited to grazing and browsing by cattle, sheep, goats, and wildlife. Stocking rate has a more important effect on the long-term stability and productivity of this rangeland than any other single management practice. Over-utilization of the forage by livestock eventually will result in greater than normal soil loss, reduced water infiltration, reduced water storage in the soil, and deterioration of the desirable vegetation (1). Often, a rancher's dilemma is how to generate adequate income without increasing animal numbers to a destructive level.

Reproductive success in Angora goats can often be low on rangeland. This occurs for several reasons. Lack of quantity or quality of forage, weather conditions, and mothering instinct of the nanny can all affect reproductive success. This situation may tempt land managers to increase production by increasing animal numbers, which can lead to overgrazing and rangeland deterioration. Improving the reproductive efficiency of Angora goats means more products (mohair and kids) can be produced without increasing the number of breeding animals.

The objectives of this study were to determine the effects of body condition before breeding on reproductive success in adult Angora nannies and to study the reproductive response of adult angora nannies in different body conditions to different levels of dietary protein before and during breeding.

Experimental Procedure

Ninety adult Angora nannies in similar body condition were separated into two groups of 45. To establish High and Low body conditions before breeding, the two groups were put into separate but similar rangeland pastures. One group was fed a 16 percent protein ration free choice; the other was not. After 41 days, each group was divided into three groups of 15, and each group was assigned one of three protein levels (17, 13.5, and 10 percent). These six groups (High 17 percent, High 13.5 percent, High 10 percent, Low 17 percent, Low 13.5 percent, Low 10 percent) were kept in confinement in groups of five and fed free choice for 14 days before breeding and for the first 37 days of a 51-day breeding season. After day 37 the nannies were kept in confinement and switched to a 16 percent ration fed at 2.5 percent of their body weight for 50 days. Approximately 31 days before kidding, the goats were moved to a small pasture and fed a 16 percent ration free choice. At the start of kidding, the nannies were put into small pens to record birth data more accurately. Kids were tagged and weighed as soon after birth as practical. Fiber measurements were not taken on the nannies.

Nannies were kept in proximity to rutting billies for 2 weeks before the start of the breeding season to help stimulate estrus. Because there were 9 billies to service 18 pens of goats, each billy was rotated between 2 pens 3 times daily.

Analysis of variance procedures for a completely random design with three replicates were used in the statistical treatment of the data. Duncan's multiple range test was used to test for differences between treatment means.

Results and Discussion

The pre-breeding treatment was used to create a High and Low body condition. All goats beginning the test in High body condition performed well reproductively. Their intake was generally lower than those goats in Low body condition fed the 17 and 13.5 percent ration. They gained less weight and appeared to be unaffected by the protein level in their feed (Figures 1, 2, 3). Goats beginning the test in Low body condition ate more of the 17 and 13.5 percent feed and gained more weight than the goats in High condition (Figures 1, 2, 3). Only when the protein level dropped to 10 percent did Low condition goats have reduced intake and appear to have reduced reproductive success (Table 1). This apparent reduction in kidding rate at the low protein level was not statistically significant, but it approached significance ($P = 0.16$) for the Low condition, low protein group. It is possible that the breeding period was long enough (51 days) to allow Low condition goats adequate time to improve their body condition if fed the 17 or 13.5 percent ration.

Reproductive rate appeared to be affected by feed intake and/or protein intake. Goats with significantly lower intake had fewer kids (Table 1). However, even though there were differences, the lowest kidding percentage still exceeded 100 percent, which is noteworthy (Table 1). Perhaps the ovulation rate is favorably affected by the protein level in the feed. This high level of reproductive success could also be the result of the

Table 1. Weights, levels of intake, and kidding rates of Angora nannies differing in initial body condition and fed different levels of protein during breeding.

	Body cond.		Protein level			Probability[a]		
Item	Low	High	Low	Med	High	BC	PL	Int
Number of animals	45	45	30	30	30			
Initial body wt, lb	84.0	84.2	82.9	85.2	84.2	.91	.70	.86
Body wt changes, lb								
Pretreatment period	-5.2^b	13.6^c	4.7	4.9	3.0	.0001	.56	.88
Treatment periods	22.4^b	15.9^c	18.2	19.6	19.6	.0001	.48	.02
Feed intake, lb/d	5.25	5.07	4.96^b	5.27^c	5.27^c	.12	.06	.09
Kids dropped (kids/doe)	1.42	1.49	1.27	1.59	1.50	.56	.12	.92

[a] Probabilities that differences between Low and High body condition groups and among low, med, and high protein level groups and the body condition x protein level interaction were due to chance.

[b,c] Means in a row not sharing a common superscript differ ($P<0.05$).

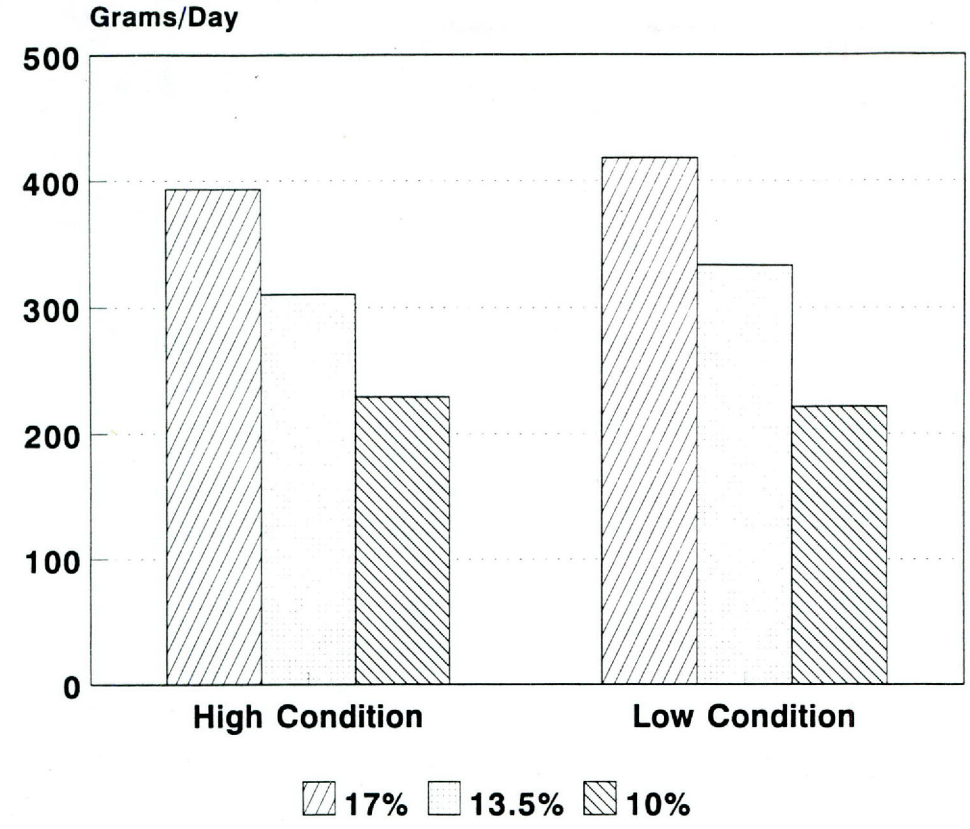

Figure 1. Protein intake of nannies in High and Low body condition fed three different protein rations.

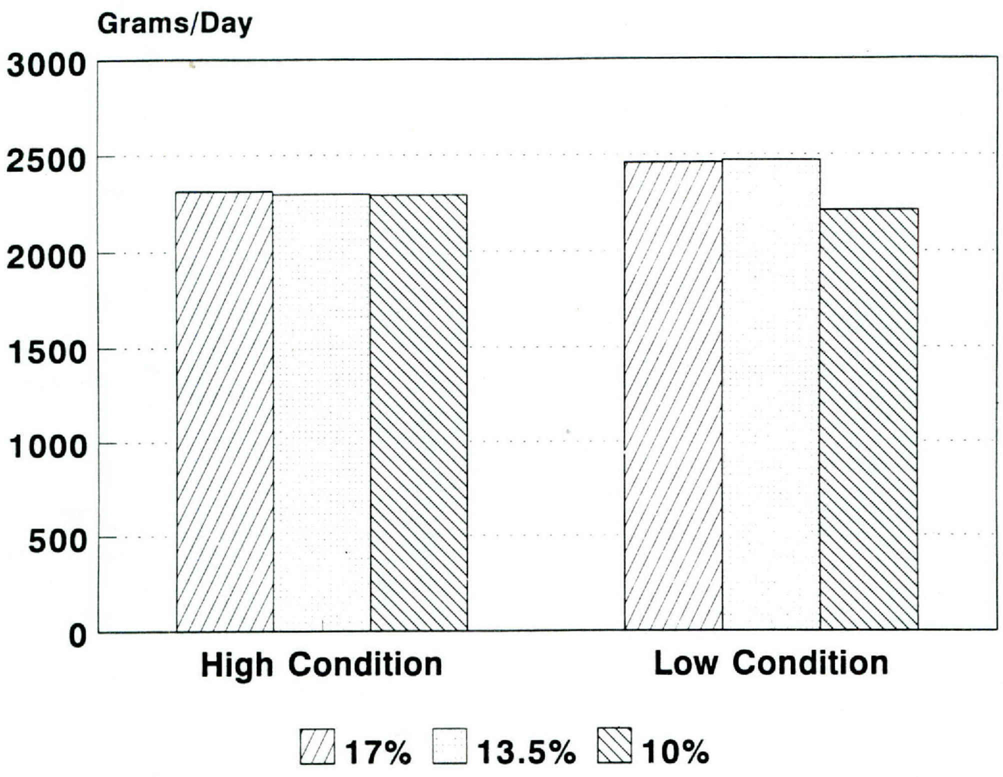

Figure 2. Total intake of nannies in High and Low condition fed three different protein rations.

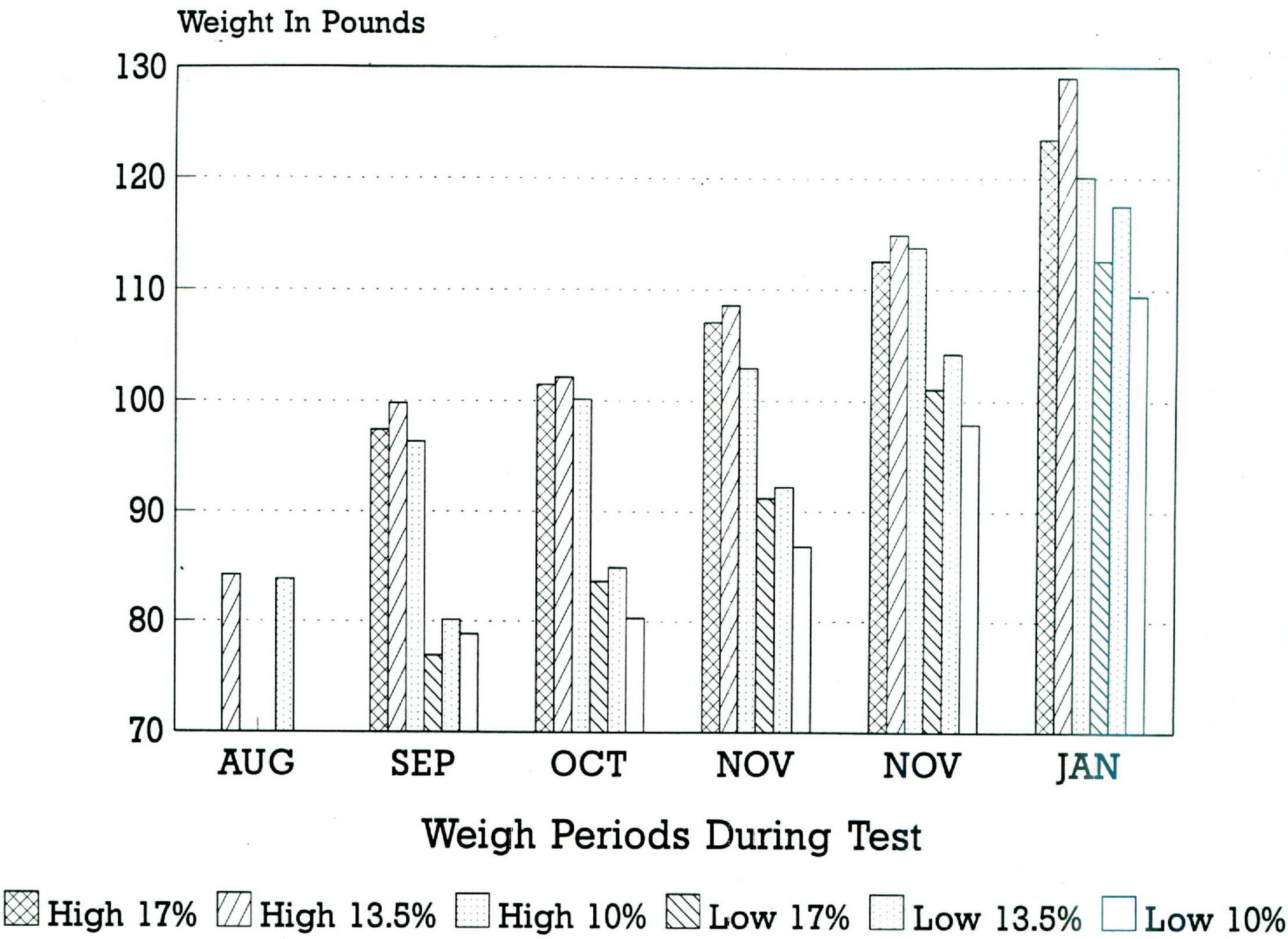

Figure 3. Nanny weights for the test period starting with the initial High/Low condition groups.

consistent feeding schedule the goats were on during the test (3).

Feeding Angora goats before breeding (flushing) can improve reproductive success (2). However, when goats are already in good condition, money spent on feed may be wasted. In addition, it has been shown that Angora nannies will substitute supplemental feed for pasture forage, resulting in no net gain in intake (1). Raising body condition before breeding and then maintaining the goat on a very low or sporadic feeding schedule can be harmful. Adequate, consistent feed throughout breeding and gestation, whether from prepared rations or rangeland forages, will help keep goat flocks more productive. This will reduce the need to raise stocking rates to increase income.

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Integration of the Fire/Picloram System and Sheep Grazing Management to Prevent Pearmouth

D.N. Ueckert, J.L. Petersen, B.K. Lawrence, and R.K. Dusek

Summary

The small spines on ripe pricklypear fruits, which are readily eaten by livestock and wildlife, cause bacterial infections in the lips and mouths (pearmouth) of sheep and goats, and the hard seeds cause rumen impaction. These health problems and the interference of pricklypear infestations with forage utilization and production and livestock handling and movement cause serious economic losses to producers.

A study was initiated in 1988 at the Texas Range Station in Crockett County to evaluate intensive management (the integrated use of prescribed fire, aerial spraying with picloram, and strategic timing of grazing of treated pastures) for alleviating the pearmouth problem in Rambouillet ewes. During 1989 through 1991, an average of only 3 percent of the ewe flock under intensive management had severe pearmouth compared with an average of 89 percent of a ewe flock under continuous grazing on adjacent pricklypear-infested rangeland. However, ewe weights at the beginning of the fall breeding season, ewe weight changes during the August-September "pricklypear apple hazard period," ewe death losses, lamb crops, and wool production were similar under intensive and conventional management systems.

Introduction

Dense stands of pricklypear (*Opuntia* spp.) interfere with forage utilization by livestock (1,5), handling and movement of livestock (2), and forage production. Ingestion of ripe pricklypear fruits by sheep and goats results in health problems that cause substantial economic losses to producers. The small spines (glochids) on the fruits cause bacterial infection in the mouths ("pearmouth") and gastrointestinal tracts, and the hard seeds cause rumen impaction (3,4). Because of the high palatability of ripe pricklypear fruits, these health problems can be substantial even in pastures with light or moderate pricklypear infestations. Consequently, sheep and goat producers need pricklypear control technology that provides a very high level of control. Our fire/picloram system (prescribed fire followed by aerial application of picloram at 0.13 to 0.25 lb/acre) is the most effective method available for controlling pricklypear on extensive areas, usually achieving over 95 percent control, and it has been economically acceptable to many ranchers ($9 to $14/acre). The effective treatment life of the fire/picloram system is estimated to be at least 15 years (6). However, it usually takes several years for a rancher to apply the fire/picloram system (or any other pricklypear control practice) to all pastures grazed by sheep and goats because of 1) limited availability of capital, 2) the difficulty of installing a prescribed fire every year, and 3) the inadvisability of burning more than 10 percent of the rangeland on a ranch in any year.

A study was initiated in 1988 at the Texas Range Station in Crockett County to evaluate the fire/picloram system as a tool for reducing pearmouth in sheep grazing tobosagrass (*Hilaria mutica*) - mesquite (*Prosopis glandulosa*) rangeland, to develop decision aids to help ranchers integrate this pricklypear management practice into their grazing and livestock management systems, and to quantify the impact of pearmouth on the productivity of ewe flocks.

Experimental Procedures

The Texas Range Station was re-fenced in 1987 to facilitate a comparison of livestock performance and economic returns from a low-input, conventional management system and a state-of-the-art, intensive management system. The conventional management system (CMS) is a 1,170-acre area that is grazed continuously at a moderate stocking rate. Range and livestock management practices that are considered "normal" for ranchers in the region are utilized in the CMS. The CMS offers little flexibility because livestock graze the entire area yearlong. The intensive management system (IMS) is a 1,260-acre area, cross-fenced with electric fences into seven, ±180-acre pastures, to allow flexibility for integration of new range and livestock management practices. Both systems are grazed by a combination of Rambouillet sheep and cattle, and both have moderate pricklypear infestations.

A 7-year rotational burning program was initiated in the IMS in 1988, with one pasture being burned during late winter each year so that the entire IMS will be burned over a 7-year period. The objectives of prescribed burning are to rejuvenate tobosagrass, improve tobosagrass utilization by livestock, suppress small mesquite plants, and to damage pricklypear sufficiently so that subsequent applications of picloram at 0.13 to 0.25 lb/acre will provide a high level of pricklypear control. The pasture scheduled to be burned is rested from mid-summer until the fire is installed in late winter to assure a sufficient standing crop of fine fuel to generate adequate heat to achieve the objectives stated above.

Following burning in late winter, the burned pasture is aerially sprayed with picloram at 0.13 to 0.25 lb/acre on about May 1. The treated pasture is grazed by cattle and/or sheep during April to early May to utilize the palatable new growth of tobosagrass, rested until mid-August, then grazed with the IMS ewe flock through September when pricklypear fruits are ripe in unburned IMS pastures. The IMS ewe flock graze untreated pastures during October through February, then they are returned to the burned-sprayed pasture during lambing season and the bitterweed (*Hymenoxys odorata*) "hazard" period, which usually coincides with the lambing season. The ewe flock in the CMS have access to abundant pricklypear yearlong.

The ewes in the IMS and CMS systems were individually examined in late September of 1989, 1990, and 1991 and assigned a score for severity of ulceration in the lips and mouth according to the scoring system described below:

Pearmouth Score	Description
0.....	No lesions or all lesions healed
1.....	One lesion on either lip
2.....	Two lesions to entire upper lip involvement
3.....	Lesions on upper and lower lips
4.....	Lesions on both lips, gums, and/or tongue

Average pearmouth scores and the percentages of ewes in each score category were calculated for each management system. Individual weights of the ewes were recorded in late September of 1989, 1990, and 1991 to facilitate a comparison of ewe weights at the end of the "pear apple" season in the two management systems. Individual weights of the ewes were recorded on July 9, 1991, and September 27, 1991, to facilitate a comparison of weight changes during the "pear apple" season in the two management systems. Ewe death losses, lamb crops, and fleece weights in the two systems were recorded each year.

Results and Discussion

Pricklypear populations have been reduced by 95 percent or more in all IMS pastures that have been treated with the fire/picloram system. Ripe pricklypear fruits were abundant in the CMS and in untreated pastures in the IMS during late August through late September of 1989, 1990, and 1991, whereas they were rare in the burned-sprayed IMS pastures. Ewes in the CMS readily consumed ripe pricklypear fruits in all 3 years of the study, as evidenced by average pearmouth severity scores ranging from 2.7 to 3.1 (mean for all 3 years = 2.9) (Table 1). The application of the fire/picloram system for pricklypear control and subsequent strategic timing of grazing of treated pastures greatly reduced availability of ripe pricklypear fruits to the IMS ewes as well as the severity and incidence of pearmouth. Average pearmouth severity scores in the IMS ewe flock ranged from 0.1 to 0.8 (mean for all 3 years = 0.5). Averaged over the 3 years, 89 percent of the ewes in the CMS suffered severe ulceration of the mouth (scores of 3 or 4) compared with only 3 percent of the ewes in the IMS (Table 2). Averaged over the 3 years, 66 percent of the ewes in the IMS were free from lip lesions, compared with only 1 percent in the CMS.

Reducing the severity and incidence of the pearmouth problem had little influence on the productivity of Rambouillet ewes over this 3-year period (Table 3). Late-September weights of ewes in the IMS tended to be slightly lower than weights of ewes in the CMS in 1990 and 1991, but these differences are not statistically significant. Average weight losses were identical (6 lb/head) for the IMS and CMS ewes during the "pear apple" season in 1991, according to ewe weight changes from July 9, 1991, to September 27, 1991.

Ewe death losses were greater in 1989 in the CMS compared with the IMS (16 versus 5 percent) (Table 3), but almost two-thirds of the total death loss in the CMS was attributed to bitterweed poisoning. Ewe death losses were slightly greater in the IMS compared with the CMS in 1990 and 1991. Lamb crops weaned over the 3-year period averaged 70 percent and 72 percent in the CMS and IMS, respectively (Table 3). Fleece weights averaged 10.1 and 9.7 lb/head in the CMS and IMS systems, respectively, during the 3-year period.

Table 1. Average "pearmouth" severity scores during late September of 1989, 1990, and 1991 for ewe flocks in conventional and intensive management systems.

	Management system	
Year	Conventional	Intensive
1989	3.1 (n=83)[1]	0.8 (n=90)
1990	2.9 (n=86)	0.1 (n=92)
1991	2.7 (n=73)	0.7 (n=76)
Average	2.9	0.5

[1]Values in parentheses are the numbers of ewes in the respective flocks.

Table 2. Frequency of occurrence (percentage of flock) of various pearmouth severity scores in ewes in conventional and intensive management systems in late September of 1989, 1990, and 1991.

	Management system							
Pearmouth	Conventional				Intensive			
severity score	1989	1990	1991	Avg.	1989	1990	1991	Avg.
				%				
0	0	1	3	1	44	92	62	66
1	0	2	6	3	28	8	10	15
2	0	8	12	7	28	0	20	16
3	87	85	75	82	0	0	8	3
4	13	4	4	7	0	0	0	0

Table 3. Mean late-September ewe weights, ewe death losses, lamb crops weaned, and mean fleece weights of ewes from conventional and intensive management systems during 1989, 1990, and 1991.

Year	Conventional	Intensive
	Late-September ewe weights (lb ± s.e.)	
1989	120 ± 2.0	123 ± 1.9
1990	128 ± 1.5	125 ± 1.4
1991	144 ± 1.6	138 ± 1.5
	Ewe death losses (%)	
1989	16	5
1990	6	8
1991	5	8
	Lamb crop (%)	
1989	59	69
1990	64	65
1991	87	82
	Fleece weights (lb)	
1989	9.8	9.0
1990	10.4	10.4
1991	10.1	9.6

These data demonstrate that intensive management, including use of the fire/picloram system for pricklypear control and strategic timing of grazing of the burned-sprayed pastures with ewe flocks, can dramatically reduce ingestion of pricklypear fruits by ewes and the severity and incidence of bacterial infections in the ewe mouths caused by small spines on the fruits. However, the ewe health problems caused by pricklypear spines had little impact on ewe weights at beginning of the fall breeding season, ewe death losses, lamb crops, or wool production under the conditions of our study. Our study has not been of sufficient duration to determine whether the productive life of ewes can be extended by eliminating the annual pearmouth problem. Significant responses to intensive pricklypear control and sheep management may be detected in future years if other management problems that may also be antagonistic to ewe productivity can be identified and corrected. Data collected during 1989 through 1991 suggest that the cross-fencing, burning, aerial spraying, and managerial inputs necessary for intensive pricklypear and sheep management are not cost effective if the only objective is to eliminate health problems in sheep caused by ingestion of pricklypear fruits.

Acknowledgment

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PR-4930

Influence of Grazing Management on Rambouillet Sheep Losses to Bitterweed Poisoning

C.A. Taylor, Jr.

Summary

Stocking rate, multi-species grazing, and grazing systems are three components of grazing management that can be manipulated to minimize losses in animal production from consumption of poisonous plants. This study evaluated two case studies for which the above components of grazing management were the experimental treatments. Study 1 evaluated three rates of

stocking, a four-pasture, three-herd grazing system, and combinations of different kinds of livestock for 21 years. Study 2 evaluated two rates of stocking, four grazing systems, and combinations of either all sheep or a 3:2 ratio of cattle to sheep (animal units [au] equivalents) for 11 years.

Sheep death losses to bitterweed (*Hymenoxys odorata* DC.) poisoning occurred in 13 of the 21 years on continuously grazed pastures heavily stocked with sheep and only 8 years under both moderate and light stocking rates. Regardless of the stocking rate, death losses were greatest on pastures stocked with sheep only and least with the combination of livestock species in conjunction with a four-pasture, three-herd grazing system.

In study 2, sheep death losses from bitterweed poisoning under continuous yearlong grazing averaged 5.2 percent compared with 3.7 percent for grazing treatments with some type of grazing system. Death losses were greatest under yearlong continuous grazing stocked at 25 au/section with 100 percent sheep and least under yearlong continuous grazing stocked at 17 au/section with 40 percent sheep.

Introduction

Poisonous plants have always been a component of rangelands; however, the problem has been increased by excessive stocking rates and poor grazing and livestock management. Livestock generally do not ingest poisonous plants in harmful amounts unless the availability and/or quality of alternate choices of forage are low (11).

Most rangelands were over grazed during the early development of the livestock industry, resulting in range deterioration. The more productive and desirable vegetation decreased with an increase in the less palatable and poisonous plant species. This phenomenon occurred because palatable plants typically put all their energy from photosynthesis into growth and reproduction, while most unpalatable species put part of their energy into compounds that discourage defoliation. The more rapid growth of the palatable species gives them an advantage under light to moderate grazing. The unpalatable species have the advantage under heavy grazing because they have less competition from death of palatable plants and because they generally receive little use (3,6).

Early records indicate that stocking rates in excess of 100 au/section were common for the Edwards Plateau in the early 1900's (14). Eventually, heavy grazing eliminated or severely reduced the better range plants, and they were replaced by less palatable, and in many instances, poisonous plants. This resulted in a decline in range condition and consequently stocking rate (Figure 1).

There are many plants capable of producing toxic metabolites, including palatable plants that are often

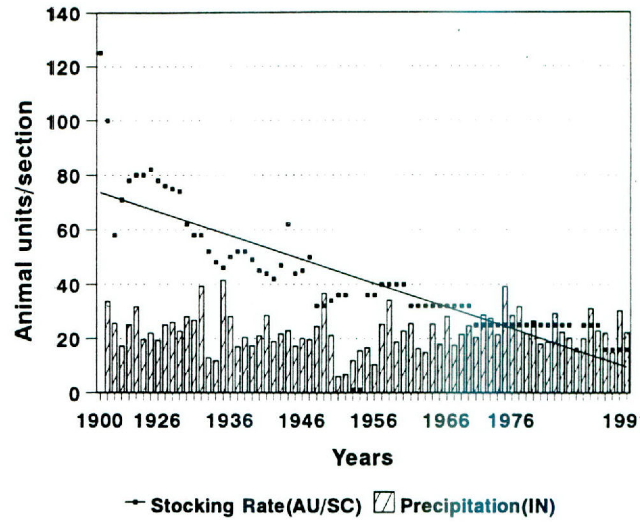

Figure 1. Stocking rate decline on the Sonora Research Station (from 1900 until 1949 stocking rate greatly exceeded carrying capacity).

important in livestock diets (10). Because of this, both researchers and ranchers have long recognized that grazing management, "the manipulation of livestock to obtain a desired result," can play an important role in reducing livestock deaths to poisonous plants.

A major part of grazing management involves decisions on stocking rate, livestock species grazed (multispecies grazing), and type of grazing system used. Stocking rate is defined as the amount of land allocated to each animal unit for the entire grazeable period of the year (9). Stocking rate probably has more influence on vegetation and livestock productivity than the other two grazing factors.

Multi-species grazing, the use of rangelands by more than one species of animal, has been advocated as a range management tool for more than 50 years (11). Research indicates that it can optimize the transfer of nutrients from vegetation to animal products (12).

Rangeland grazing systems were initially developed to provide periodic rests to allow the more preferred plants to recover from defoliation. Early strategies placed more emphasis on range improvement than on animal performance. When properly managed, grazing systems can reduce the incidence of poisoning in grazing animals.

This paper presents results from two case studies dealing with grazing management and discusses the consequences of manipulating grazing management on the frequency and intensity of plant poisoning in livestock.

Experimental Procedure

Study 1 was conducted on the 3,500-acre Texas A&M University Experiment Station located 28 miles south of Sonora, Texas. The rolling, stony hill topography that characterizes the Station is typical of the Edwards Plateau. Annual total precipitation is extremely variable and ranges from 6.1 to 41.5 inches with an average of 23.9 inches.

The vegetation is a complex mixture of grasses, forbs, and woody species (4,8). Woody plants include live oak (*Quercus fusiformis* Small), ashe juniper (*Juniperus ashei* Bucholz), and honey mesquite (*Prospis glandulosa* Torr.). Common bunchgrasses are sideoats grama (*Bouteloua curtipendula* Michx.), Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.), and threeawn (*Aristida* spp.). Dominant short grasses are curlymesquite (*Hilaria belangeri* Steud.), red grama (*Bouteloua trifida* Thurb.), and hairy tridens (*Erioneuron pilosum* Nash).

The grazing treatments, evaluated over 21 years (1949-1970), included three rates of stocking (a four-pasture, three-herd grazing system) and combinations of different kinds of livestock. The three stocking rates were heavy (48 au/section), moderate (32 au/section), and light (16 au/section). Continuous yearlong grazing was compared with a four-pasture deferred rotation system. The combination of animals grazed were cattle, sheep, and goats grazed alone; cattle and goats (1:1 au ratio); and cattle, sheep, and goats (2:1:1) (7).

Study 2 was conducted in the northwestern portion of the Edwards Plateau on the Texas Range Station, 21 miles north of Ozona, Texas, at an elevation of 2,600 feet. The terrain is a relatively flat upland. Scattered shallow depressions and playa lake beds occur throughout the lower portion of the landscape. Precipitation occurs mostly as rainfall during spring and fall peaks. Average annual precipitation from 1941 to 1989 was 20 inches and ranged from 9.6 to 46.2 inches.

Vegetation of the study area is described as an open savanna dominated by a mid-grass, Tobosa, (*Hiliaria mutica* Benth.) and stoloniferous short-grasses, curly mesquite, and buffalograss (*Buchloe dactyloides* Engelm.). Honey mesquite is the dominant woody species on the study area.

A 14-year non-replicated grazing study (1956 to1970) consisting of seven treatments was implemented on the Range Station. The grazing treatments included yearlong grazing of sheep at 25 au/section; yearlong grazing of cattle and sheep (3:2 au equivalent ratio) at 25 au/section; four-pasture, three-herd grazing system with cattle and sheep (3:2) at 25 au/section; six-pasture, one-herd grazing system with cattle and sheep (3:2) at 25 au/section; two-pasture, one-herd grazing system with cattle and sheep (3:2) at 25 au/section; and yearlong grazing of cattle and sheep (3:2) at 17 au/section.

Results and Discussion

Study 1

Bitterweed (*Hymenoxys odorata* DC.), a cool-season annual forb, is generally considered the most serious poisonous plant problem affecting the sheep industry in Texas (10). It is unpalatable and poisonous at all times. Sheep consume the plant only when forced to do so by lack of palatable forage (4). Over-grazing of rangeland has increased the quantity and range of bitterweed (5). The plant vigorously grows on disturbed areas or where other vegetation is scarce.

Bitterweed toxicity problems are most likely to occur when there is sufficient soil moisture in the fall to germinate and establish the plants, followed by a dry late winter and spring. Most sheep losses to bitterweed poisoning occur in the winter and early spring (Figure 2).

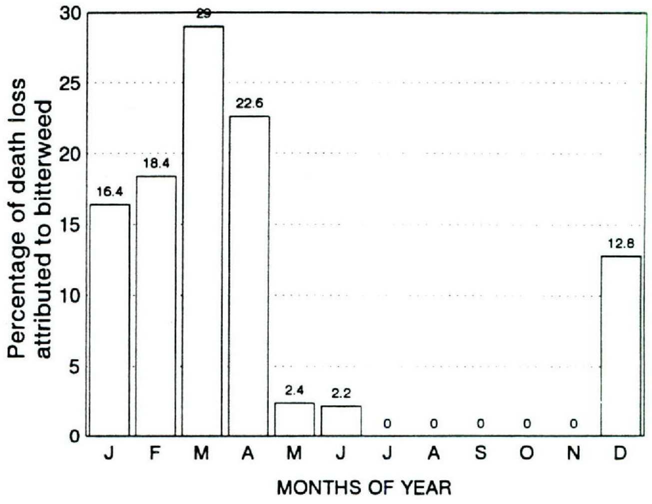

Figure 2. The mean percentage of total sheep death loss attributed to bitterweed poisoning on the Sonora Research Station (21 years).

Grazing management was important in reducing sheep losses from bitterweed poisoning. Sheep death losses to bitterweed poisoning occurred in 13 of the 21 years on continuously grazed pastures heavily stocked with sheep and in only 8 years under moderate and light stocking rates. Regardless of the stocking rate, death losses were greatest on pastures stocked with sheep only and were least with the combination of livestock species in conjunction with a four-pasture, three-herd grazing system (Figure 3).

Study 2

A major problem with extensive grazing studies is knowing the exact cause of animal death especially when poisonous plants are present. In this study, not all animals were autopsied, but most deaths occurred during periods of the year when bitterweed was known to be a problem.

The pasture stocked at 25 au of sheep/section and grazed yearlong had the greatest death loss (Figure 4). The lowest death loss of ewes occurred from the 40 percent sheep pasture stocked at 17 au/section. Sheep death losses in continuous, yearlong grazing treatments

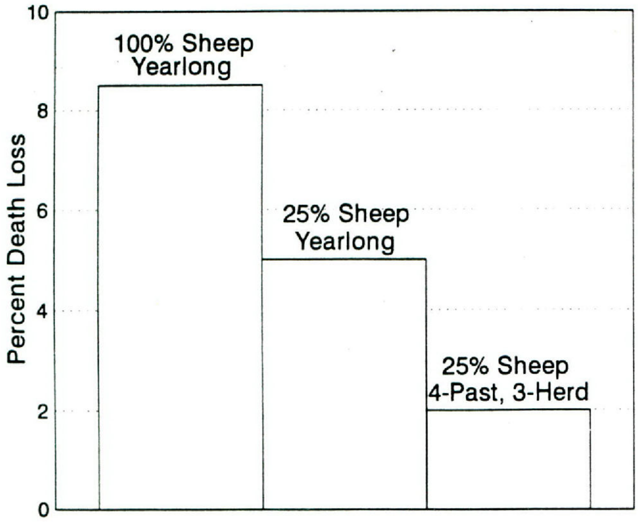

Figure 3. Average death losses (%) of sheep attributed to bitterweed poisoning from three different grazing treatments on the Sonora Research Station (21 years).

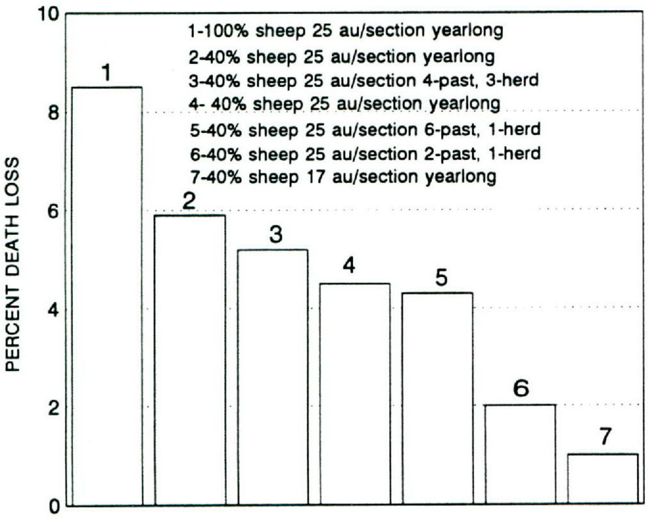

Figure 4. Average death losses (%) of sheep attributed to bitterweed poisoning from seven different grazing treatments on the Texas Range Station at Barnhart (14 years).

averaged 5.2 percent versus 3.7 percent for grazing treatments with some type of grazing system.

Because treatments were not replicated for this study, no statistical analysis for significant differences was conducted; however, the results tend to support other data that indicate 1) death losses can be reduced if combinations of animal species are grazed together rather than alone; 2) reduced stocking rate will reduce death losses, and; 3) grazing systems help reduce death losses at moderate stocking rates (1,7,13).

These data show that grazing management alone will not eliminate sheep death losses caused by consumption of poisonous plants. However, losses can be reduced through proper grazing management. The different management schemes that could be employed to manage for a particular poisonous plant problem are infinite. The key to success in minimizing poisonous plant problems is accurate information and the ability to integrate this information into a management plan. Tactical management decisions such as proper stocking rate, combinations of animal species to be grazed, and grazing system used will be critical to success.

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PR-4931

Ceroid Lipofuscinosis, an Inherent Form of Blindness in Sheep

Maurice Shelton, Carl Menzies, Tim Willingham, Ralph Storts, and Phillip R. Woods

Summary

A semi-lethal or delayed lethal condition is described in sheep. The most obvious symptom is blindness, which develops in the period 6 to 15 months of age. The condition known as neuronal ceroid lipofuscinosis (NCL) results in death by, or before, 2 years of age. At necropsy, lesions are largely restricted to the brain. The condition is a neurodegenerative disorder suspected to be a proteolipid proteinosis in which an abnormal accumulation of a proteolipid (Ceroid-Lipofuscin) develops within neurons in the brain. A similar condition has been previously identified in cats, dogs, sheep, cattle, goats, and humans. Previous studies and experiences indicate that it is genetic in origin. Controlled matings in this study strongly suggest that it is a simple autosomal recessive condition. This is the first known time that the disease has been identified in sheep in this country.

Introduction

In the past few years, a number of cases of blindness in sheep, which were not explained by conjunctivitis, have been reported to scientists at this center. Superficially, the eyes of affected sheep appear normal. The condition has been observed in four flocks of range finewool sheep (purebred and commercial). Each of the four flocks were closely related genetically. In addition, a limited number of animals showing this defect have been observed in commercial market channels. The condition has now been generated by controlled matings in an experimental flock.

At birth, the affected animals appear to be normal; the condition manifests itself clinically in the range of 6 to 15 months of age under field conditions. Vision impairment as late as 15 months is probably unlikely, but in a group on pasture, affected animals up to this age are able to remain with the flock, apparently using their other senses. Under field conditions, affected animals have not been known to reproduce, but under controlled conditions they may be stimulated to do so before symptoms become extreme.

Symptoms

The first symptom under field conditions is visual impairment. When affected sheep are isolated, the condition is often readily apparent, whereas when they are in a group, it may be some time before it is apparent. As the condition becomes more extreme, it is obvious that a much more involved neurological syndrome exists. Eventually affected animals wander aimlessly, frequently becoming isolated from the flock and extending their heads as if "star-gazing" (see Figure 1). In more advanced cases, the animal circles almost constantly. Although the number of observations is limited, the affected animals invariably lose condition and die at 2 years of age. Their life span is extended by placing them in confinement near feed and water.

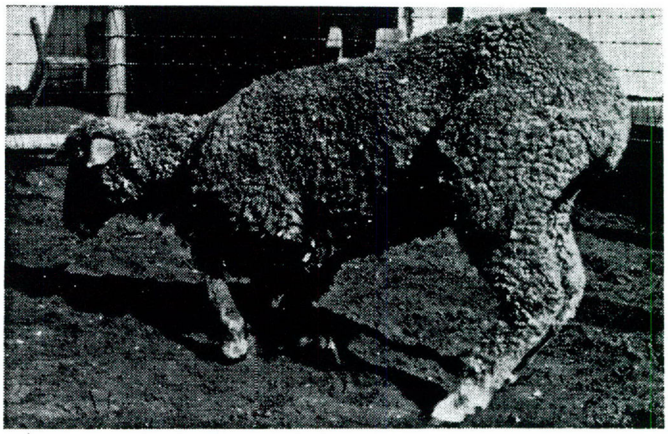

Figure 1. An affected animal in the advanced stages of the disease.

Etiology

Detailed laboratory investigation (9,8) has confirmed the condition as neuronal ceroid lipofuscinosis (NCL), a neurodegenerative disorder suspected to be a proteolipid proteinosis in which an abnormal accumulation of proteolipid (Ceroid-Lipofuscin) develops in the brain. At autopsy, lesions (abnormalities) are largely restricted to the brain. NCL has previously been identified in a number of species including cats (1), dogs (2), sheep (3), cattle (4), goats (5), and humans (6). The condition is similar in all species, except that in humans at least four different subtypes are recognized. Some species appear to differ in the age of onset.

Previous work with Hampshire sheep in New Zealand (3) as well as with other species has strongly suggested that the condition is genetic in origin. Results of the investigation reported here seem to confirm a hereditary basis in that all the four affected flocks were closely related genetically through use of the same or related rams. The general assumption has been that it is due to a single autosomal recessive gene. If it were due to a single gene, it could not function as a dominant because a dominant lethal gene would be eliminated from the population.

Experimental Procedure

In the summer of 1990, a number of affected animals, or animals known to be carriers or likely carriers (from pedigree information and the assumption of a recessive gene), were accumulated and delivered to the Texas Agricultural Experiment Station at San Angelo. Several controlled matings were made among these. The results are shown in Table 1. The females available for breeding were either affected (blind) or were ewes sired by known carrier rams (assuming a simple recessive inheritance) and thus had at least a 50 percent chance of being carriers. Available rams included affected (blind) animals and known carrier males.

In no cases were the affected animals successfully bred naturally. Four offspring were produced from blind rams by use of electro-ejaculation and artificial insemination. Efforts were made to obtain offspring from blind females by controlled (endocrine-stimulated) ovulations (following insemination with semen from affected males) and embryo transfer. It was apparent that these animals were not good source candidates for this procedure. Only one fertilized ovum was collected that resulted in the birth of one offspring. For control purposes, especially for laboratory studies, a single animal was included that had normal parents with no known relationship to the affected animals.

Results and Discussion

The results of controlled matings are shown in Table 1. If the probability figures in column four are added, the sum equals 4.50, which suggests that the number of affected animals from this group should be four or five because fractional values are not possible. In fact, five animals from this group have been identified as affected. This is consistent with the expectation that the condition is due to a single autosomal recessive. Further evidence of this is that the obligate normal animal was normal and the obligate blind animal was blind. Two of the remaining four blind animals came from the group sired by a blind ram. The other two came from the group of 20 animals, which each had a 12.5 percent probability of being blind. Thus, the number of affected animals closely approximates that expected according to the hypothesis of a simple recessive. In addition, three animals are currently classified as "suspect" (12 months of age). The results of electroretinograms made at approximately 5 months of age indicate that all males were considered normal and all except one (one of the suspects cited above) were marketed shortly thereafter.

A reinterpretation of the results, based on a more recent experience, suggests that the retained male may have been positive for the condition. The two other

Table 1. Results of controlled matings.

Offspring No.	Sex	Genotype of sire	Genotype of dam [% probability of being a carrier]	Probability off-spring will be... Blind	Carrier	Non-carrier	Off-spring status
2	M	Carrier	50	.125	.5	.375	Normal
4	F	Carrier	50	.125	.5	.375	Normal
5	M	Blind	50	.25	.75	0	Normal
7	F	Blind	50	.25	.75	0	Pos.
8	M	Carrier	50	.125	.5	.375	Normal
10	M	Carrier	50	.125	.5	.375	Normal
12	M	Blind	50	.25	.75	0	Pos.
14	F	Carrier	50	.125	.5	.375	Normal
18	F	Carrier	50	.125	.5	.375	Suspect
19	F	Carrier	50	.125	.5	.375	Normal
20	M	Carrier	50	.125	.5	.375	Suspect
21	M	Carrier	50	.125	.5	.375	Normal
22	F	Blind	100 (blind)	1.00	0	0	Pos.
23	F	Carrier	50	.125	.5	.375	Normal
24	F	Normal (not carrier)	0	0	0	1.00	Normal
25	F	Carrier	50	.125	.5	.375	Normal
26	F	Carrier	50	.125	.5	.375	Normal
27	F	Carrier	50	.125	.5	.375	Normal
28	F	Carrier	50	.125	.5	.375	Normal
29	F	Carrier	50	.125	.5	.375	Pos.
30	F	Carrier	50	.125	.5	.375	Pos.
31	M	Carrier	50	.125	.5	.375	Normal
32	F	Carrier	50	.125	.5	.375	Normal
33	F	Carrier	50	.125	.5	.375	Normal
35	F	Carrier	50	.125	.5	.375	Normal
37	F	Carrier	50	.125	.5	.375	Normal
38	F	Carrier	50	.125	.5	.375	Normal

"suspect" animals are still in the flock and their status will be clarified later. If the suspect animals are later classified as "affected," there would be a non-significant excess of affected animals.

Because the experimental animals (especially females) came from flocks in which the gene is known to exist, the actual gene frequency for the condition in the experimental females was almost certainly higher than that shown. This could not have been true for the males used for breeding because their genotype for the condition was known. Additional test matings are being made.

NCL should be viewed as a delayed lethal condition. The animals can be marketed for meat if they are well fed to obtain weight and market condition and are marketed before clinical symptoms develop. It is not known or expected that the heterozygous state has any adverse effects.

Because the condition has been observed in a number of species, and in at least two unrelated or geographically separated breeds of sheep, it appears that this mutation has spontaneously occurred in more than one instance - a high mutation rate from the normal to the defective. This condition should be considered as undesirable, but it probably does not constitute a major threat to the sheep industry. Once the gene is present, it would be nearly impossible to totally eliminate this condition from the population. However, in pedigreed flocks the clinical manifestation of the disease can be largely eliminated by purging the flock of all suspected carriers based on pedigree. This has been accomplished with a high degree of success in a short period of time in some of the affected flocks.

For the producer not familiar with the actions of recessive genes, their expressions in the flock would be similar to that for recessive black color, which is found in most flocks of fine-wool sheep. In random mating flocks, or at least in random matings in respect to this condition, the gene frequency from NCL in the flock can be calculated as the square root of the percentage showing the defect. For each defective animal there will be at least two carriers in the flock that are not observed.

The current experimental population is being maintained and should hold interest as a source of experimental animals for use as a model for the study of the condition in all species, including humans, and as a test flock to facilitate attempts to eliminate the gene from producer flocks.

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Cache Valley Virus-Induced Oligohydramnion and the Possible Relationship of Oligohydramnion to Lamb Malformation and Stillbirth

J.F. Edwards, S.I. Chung, A. de la Concha-Bermejillo, and E.W. Collisson

Summary

Pregnant ewes between 38 and 42 days of gestation were inoculated in utero with Cache Valley virus (CVV) to study the occurrence of oligohydramnion (reduced amniotic fluid) in infected fetuses. There was a significant difference between the 18 infected lambs (average amniotic fluid volume 49 ml) and the 16 control lambs (average amniotic fluid volume 432 ml). The allantoic fluid volume of infected lambs was unaffected. The constriction of the amniotic membrane may account for arthrogryposis and twisted spines observed in CVV-infected lambs without nervous system or muscle lesions. In addition, oligohydramnion may explain the occurrence of weak and stillborn lambs in natural outbreaks of CVV.

Introduction

It has been established that Cache Valley virus (CVV) infection can produce malformations in sheep. Experimentally, arthrogryposis (limbs fixed in flexed position), torticollis (head twisted over to the side or laterally), scoliosis (lateral deviation of the spine), hydranencephaly, and cerebellar dysplasia have been produced in lambs by in utero CVV inoculation. These experimental lesions are identical to those reported in field outbreaks of CVV malformations in sheep.

Since our initial work, outbreaks of CVV-induced malformations of ovine fetuses have been documented in Michigan, Nebraska, Illinois, Delaware, Pennsylvania, and Maryland. Therefore, CVV is not a pathogen unique to Texas.

During studies of CVV-induced malformations, we have sought mechanisms to explain stillbirths and arthrogryposis recorded in lambs with no apparent lesions to explain these abnormalities. In a previous study, oligohydramnion was observed in lambs born to ewes infected with CVV at gestation day 38-42.

This study was done to investigate possible relationships of CVV infection to oligohydramnion and the possibility that CVV-induced constriction of fetal membranes could cause arthrogryposis.

Experimental Procedure

A total of 19 ewes (9 controls and 10 infected) were used in two trials. The ewes were inoculated in utero at from 39 to 42 days of gestation with either 10^5 $TCID_{50}$ of CVV or an equal volume of tissue culture medium. The ewes were then housed in isolation until 28 to 30 days after inoculation, when they were killed and the uterus and fetuses were collected for examination. The total volumes of amniotic and allantoic fluid were measured and samples of fetal tissues, membranes, and fluids were collected for virus isolation and histopathologic examination.

Results and Discussion

The results of fluid volume measurements are given in Table 1. Because all controls were twins, only data from ewes with infected twin fetuses were compared. Only one fetal death was recorded, and significant oligohydramnion was routinely observed. There was no change in allantoic fluid volumes. The allantoic fluid had an increased viscosity in infected lamb fetuses and, at times, formed a gel that made volume measurement difficult in infected fetuses.

Lambs with oligohydramnion were observed to have varying degrees arthrogryposis, torticollis, and scoliosis that corresponded to the decrease in volume of the amniotic fluid. That is, fetuses with small volumes of amniotic fluid (4 to 30 ml) were contained in a constricted amniotic sac and had contracted limbs and severely twisted spinal columns, while fetuses with greater amniotic fluid volumes, more than 30 ml and less than 150 ml (the average normal amniotic fluid volume being 426 ml), had only a single limb or the neck affected. Two fetuses, cotwins/siblings to affected fetuses, that were from infected ewes did not have oligohydramnion.

The finding of only one of two twin fetuses affected in two sets of infected twins was interpreted as being a

Table 1. Average volumes of fetal fluids in CVV trials.

Trial	Amniotic fluid (mls)		Allantoic fluid (mls)[a]	
	Infected	Control	Infected	Control
1	49 (n = 9)	432 (n = 8)	85 (n = 5[c])	40 (n = 8)
2	76 (n = 8[b])	420 (n = 8)	36 (n = 7[b])	38 (n = 8)

[a]Only twins compared.
[b]Two fetuses not included because of inoculation failures.
[c]Four allantoic sacs ruptured during sampling.

failure to successfully inoculate both fetuses. It also demonstrates that the virus does not always travel within the uterus between fetuses. If fetuses share a common allantoic cavity, the virus would infect both fetuses although the virus entered only one. In outbreaks, only one of sets of sibling lambs may be affected, and our results reflect the natural condition in which each fetus must be infected to be malformed.

Virus isolation has been successful only from the fetal membranes and fluids, particularly allantoic, while fetal tissues and blood are negative for virus isolation. Degeneration and necrosis of fetal tissues were not apparent histologically.

Arthrogryposis has traditionally been attributed to diseases that affect the central nervous system or muscles. The pathogenesis is believed to be related to the effect of an infectious agent or plant toxin on muscle or nervous tissue so that the limbs contract from lack of movement. The results of this study indicate that a constrictive amniotic sac may prevent the fetus from free movement so that the limb is born with reduced range of movement of limbs.

In humans, twin fetuses competing for limited space, abnormal placental bands, and oligohydramnion early in pregnancy have been seen with arthrogrypotic lesions. However, CVV is the first virus studied that produces this lesion in domestic animals.

The mechanism by which oligohydramnion occurs is being investigated. In early gestation, the fetal fluids are primarily the result of the active metabolism of the placental membranes. Later in gestation, fetal urine and oral and pulmonary secretions supply most of the fluids that bathe the fetus. We propose that persistent fetal membrane infection prevents normal passage of fluids and solutes through the membranes and causes oligohydramnion in young fetuses. This hypothesis is supported by our finding of virus only in the fetal membranes 4 weeks after infection. Although no lesions are seen in infected membranes, the persistent infection of the allantoic membrane may have made the allantoic sac more fragile leading to the rupture of four sacs during our dissections (see Table 1). We hope to investigate this further by looking at membrane infection with a nucleic acid probe for CVV. We also hope to catheterize fetal fluid spaces in infected ewes and follow the effect of CVV on ion (and therefore fluid) exchange in infected fetuses.

Oligohydramnion may have further importance to infected fetuses. Reduced amniotic fluid has been causally linked to human pulmonary hypoplasia. Future studies will investigate the relationship between CVV infection later in gestation and stillborn and weak lambs without viral-induced lesions.

Cache Valley virus persists as a significant pathogen when it is endemic in sheep-raising areas. The mechanisms leading to its virulence need to be further studied to control its occurrence and to develop possible treatment of weak lambs born during outbreaks. Such activity will reduce future lamb losses.

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Isolation of an Ovine Lentivirus from a Ram in Texas

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

Summary

A lentivirus was isolated from a Suffolk ram in Texas. The lentivirus was identified as ovine lentivirus (OvLV) by amplifying a DNA segment of the long terminal repeat (LTR) of the OvLV genome, using the polymerase chain reaction (PCR) technique, and by immu-

nocytochemistry. Because serological evidence indicates that ovine lentivirus (OvLV) infections are almost non-existent in Texas, the isolation of OvLV in Texas is considered significant. Lentivirus infection in sheep induce chronic multisystemic disease that can result in serious economic losses. The risk of introducing OvLV-infected animals into OvLV-free areas is discussed.

Introduction

Lentiviruses are a group of related viral agents that cause chronic, multisystemic diseases in humans and domestic animals. Lentivirinae (slow viruses) is a subfamily within the virus family Retroviridae (18). Ovine lentivirus (OvLV) infection in sheep may result in a condition called ovine progressive pneumonia (OPP), known also as visna/maedi. This disease is characterized by a variety of clinical syndromes that include chronic weight loss, pneumonia, arthritis, mastitis, and encephalitis (4).

OvLV infection is widespread in North America, especially in the West (3,5,11). Ovine lentivirus was first isolated in 1953 by Siggurdson, although OvLV-associated diseases had been recognized for at least five decades previously in Europe, South Africa, and North America (7). A survey of culled ewes in the western United States revealed serological prevalence rates that ranged from 1 to 68 percent, and four states (Idaho, Utah, Colorado, and California) had prevalence rates of more than 30 percent. The reported seroprevalence of OvLV in a small sample of culled ewes from Texas was 1 percent (3).

To increrase understanding of the epidemiology of OvLV infection in Texas, we have been collecting sheep serum samples. To date, 905 serum samples collected in 27 different Texas locations have been tested for the presence of OvLV antibodies. One hundred serum samples from a ram progeny test have also been tested. Nine sheep (0.89 percent) out of 1,005 tested had serologic evidence of exposure to OvLV. The nine positive reactors were from five different locations in west-central and north-central Texas. The origin of eight of the nine positive sheep was traced to three states: Idaho (one Suffolk ram), Iowa (three Suffolk ewes), and Missouri (three Finn/Dorset Rams and one Polypay ewe). The ninth sheep had been bought at an auction and the origin was unknown (10). To our knowledge, the isolation of OvLV in Texas has not been reported.

The objective of the present report is to document the isolation of an ovine lentivirus from a sheep in West Texas and to discuss some of the risks of introducing OvLV-infected animals into Texas.

Materials and Methods

Clinical Case. During an epidemiological survey of OvLV infection in Texas, one sheep identified by agar gel immunodiffusion (AGID) test as being OvLV-exposed was acquired and maintained in an isolation pen. The animal, identified as 91S2, was a 5-year-old Suffolk ram. A Rambouillet ram (91S3) experimentally inoculated with OvLV strain 85/34 was used as positive control. A seronegative and polymerase chain reaction (PCR) negative Rambouillet ram (91S7) was used as negative control.

Agar Gel Immunodiffusion Test for OvLV. OvLV-precipitating antibodies were detected by the AGID test, using a commercially available kit (Veterinary Diagnostic Technology, Inc., Wheat Ridge, CO). A positive result was scored when a precipitin line was formed between the test serum well and the antigen well and when this line joined the precipitin line of the positive control reagent serum to form a continuous line of identity.

Mononuclear Cell Separation. Peripheral blood mononuclear cells (PBMNC) were separated by Ficoll-Hypaque density gradient centrifugation. Separated cells were used for virus isolation and PCR analysis.

Virus Isolation. Primary cultures of goat synovial membrane (GSM) cells were used to isolate OvLV from peripheral blood mononuclear cells of the seropositive ram. PBMNC from a seronegative- and PCR-negative sheep (91S7) were used as negative controls. Ovine lentivirus strain 85/34 and PBMNC from an experimentally infected sheep were used as positive controls. The GSM cells were grown in minimal essential medium (MEM) supplemented with 10 percent heat-inactivated fetal bovine serum (Gemini Bioproducts, Inc., Calabasas, CA), 10 mg/ml L-glutamine, 10,000 units/ml sodium penicillin G, and 10 mg/ml streptomycin sulfate (Gibco, Grand Island, NY) (2).

To detect infectious OvLV, GSM cell monolayers were inoculated with 4×10^6 PBMNC. Cultures were monitored at 48-hour intervals for evidence of cytopathic effect (CPE) and passed three times at 10-day intervals before being scored (2). Cultures were confirmed as positive or negative by immunocytochemistry and by the PCR.

Immunocytochemistry. The isolate was confirmed as OvLV by immunocytochemistry using an avidin-biotin peroxidase complex procedure (Vectastain ABC kit, Vector Laboratories, Burlingame, CA). As primary antiserum, we used a monoclonal antibody (2F) specific for the OvLV capsid (p25) antigen (2). Goat synovial membrane cells infected with OvLV strain 85/34 were used as positive controls. Non-infected GSM cells and GSM cells infected with PBMNC from the seronegative ram (91S7) were used as negative controls. Sets of GSM cells in which the primary antibody was avoided were also included.

Polymerase Chain Reaction. Extraction of DNA from the GSM cell monolayers co-cultivated with the PBMNC was done with non-ionic detergents and proteinase K digestion. Polymerase chain reaction (PCR) was performed as previously described (2). One microgram of extracted DNA was amplified through 25 cycles of PCR in 50 Mm KCL, 10 Mm Tris-HCL (Ph 8.3), 2.5 Mm $MgCl_2$, 200 µmol of each deoxyribonucleotide triphosphate, 10 pmoles each of upstream and downstream primer, and 2.5 units of the thermostable *Thermus aquaticus* (Taq) DNA polymerase. OvLV primer pairs specific for the long terminal repeat (LTR) that amplify a 280 bp segment were used (2,9). The reactions were performed in an automated DNA thermocycler (Perkin Elmer Co., Norwalk, CT) using our defined conditions (1 min. at 95°C for target denaturation; 1 min. at 55°C for primer annealing; 3 min. at 72°C for primer extension). One-tenth volume of amplified DNA product was resolved by electrophoresis in 4 percent agarose gels (1:3 Seakem and NuSieve agarose, FMC Bioproducts, Rockland, ME) and was visualized by ethidium bromide staining. Steps to avoid contamination included the use of single-aliquoted reagents and aerosol-free pipet tips. In addition, cell preparation and enzymatic amplification were carried out in separate locations. Positive and negative controls consisting of DNA extracted from OvLV-infected and non-infected GSM cells were included. Samples containing all the components of the PCR reaction mixture but without DNA were also included as controls of DNA contamination.

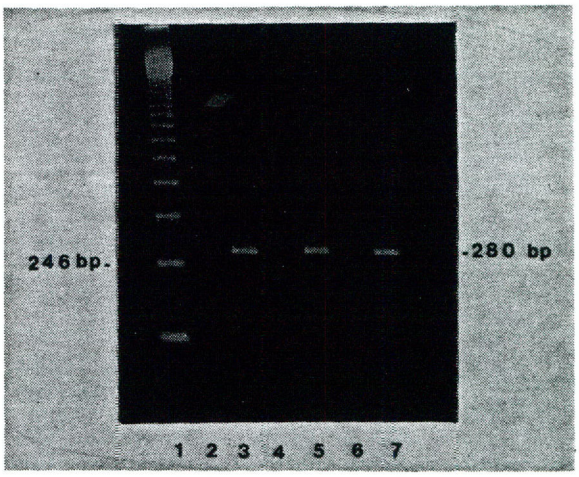
Results

The 91S2 ram has been maintained in an isolation pen for 9 months. This animal has not shown evidence of OvLV-related disease. Agar gel immunodiffusion test has been OvLV-positive every other week since the animal was first tested on July 1991. The experimentally inoculated ram (91S3) seroconverted at 6 weeks after inoculation. The negative control (91S7) has remained seronegative throughout this time.

Cytopathic effects (CPE) consisting of focal areas of lysis and the presence of giant multinucleated cells (syncytia) were observed in the GSM monolayer infected with PBMNC of ram 91S2 after 10 days of the second passage. After a third pass, the CPE did not progress to complete destruction of the monolayer but rather remained as focal areas of lysis with persistent syncytia. On the other hand, the positive controls (monolayer infected with OvLV strain 85/34 and monolayer infected with PBMNC of sheep 91S3) showed CPE 7 days after inoculation and progressed to massive destruction of the monolayer within 6 days after CPE was first observed. No CPE was observed in the monolayer infected with PBMNC of ram 91S7.

OvLV-immunoperoxidase-stained cells and syncytia were observed in the GSM monolayers infected with PBMNC of ram 91S2 and in the positive controls. No staining was observed in the GSM monolayer infected with PBMNC of ram 91S7.

Lentiviral LTR-DNA was detected in GSM monolayer infected with PBMNC of ram 91S2 and in the positive controls, but not in the GSM cells infected with PBMNC of ram 91S7 or in the non-infected GSM cells (Figure 1).



Line 1. Molecular weight markers.

Line 2. Non-infected GSM cells.

Line 3. GSM cells infected with OvLV strain 85/34.

Line 4. No DNA.

Line 5. GSM cells infected with PBMNC from ram 91S2.

Line 6. GSM cells infected with PBMNC from ram 91S7.

Line 7. GSM cells infected with PBMNC from ram 91S3.

Figure 1. OvLV-LTR products amplified by the polymerase chain reaction, separated by agarose gel electrophoresis, and stained with ethidium bromide.

Discussion

In this report the isolation of an ovine lentivirus from a ram in West Texas is documented. The ram had been bought in an auction and introduced into a Texas ranch approximately 1 year before OvLV isolation. Fifty eight Rambouillet ewes, out of 100 in contact with the ram, tested OvLV-negative by the AGID test 8 months after the ram was removed from the ranch (10). However, 1 lamb (out of 40 tested) from the mating of the infected ram to the Rambouillet ewes was OvLV-positive when tested at 4 months of age.

It is not possible to determine whether the antibodies detected in this lamb were the result of maternal antibody transfer through the milk or were the result of an antibody response of the lamb to OvLV infection. Because the lamb was not in direct contact with the infected ram, the presence of antibodies in its serum would suggest that the mother of this lamb was infected.

Efforts to test all the ewes in contact with the infected ram in this ranch are now being conducted. Because all the ewes were not tested for OvLV antibodies before being in contact with the ram, it will not be possible to determine if the mother of the seropositive lamb was infected through contact with the infected ram.

Ovine lentivirus isolates have been grouped as lytic and non-lytic. Lytic strains induce rapid syncytia formation in fibroblasts followed by monolayer lysis within 6 to 9 days. Non-lytic strains induce slowly progressive syncytia with minimal monolayer lysis by 12 days (16). The in vitro characteristics of the OvLV isolated in our laboratory indicate that it is a non-lytic strain. In vitro differences in strain cytopathogenicity have been correlated with in vivo pathogenicity (17).

Neonatal lambs inoculated with lytic strains develop severe lymphoid interstitial pneumonia (LIP). Those inoculated with non-lytic strains develop mild LIP or no disease. However, mutation of some isolates from non-lytic to lytic during the course of infection have been reported (9).

Epidemiological studies indicate that evidence of ovine lentivirus infection in Texas is almost non-existent (3); whereas prevalence of OvLV in other sheep-producing states such as California, Colorado, Idaho, and Utah has been reported to be higher than 30 percent (3,5,11). The reasons for this difference in OvLV seroprevalence are not clear but may be related to several factors: 1) The most common breed of sheep in West Texas is Rambouillet. Epidemiological studies suggest that Rambouillet sheep may be more resistant to OvLV infection. 2) Climatic conditions in West Texas (hot and dry) may not favor the transmission of OvLV by close contact. 3) Most Rambouillet producers maintain closed flocks or buy native replacement sheep. 4) Most lambing in West Texas takes place on the range; therefore, housing, crowding, and close contact between ewes does not occur during lambing.

OvLV is transmitted primarily through the colostrum and, less frequently, vertically to the fetus. Increased seroprevalence with increased age suggests that transmission through close contact also occurs (6,8). It is not known whether OvLV can be transmitted horizontally under Texas-type conditions. Research on OvLV transmission is needed to prevent the possible spread of OvLV into Texas.

In 1933 visna/maedi was introduced into Iceland with the importation of Karakul sheep from Germany. Losses caused by visna gradually increased over several years and reached 15 to 30 percent annually in some flocks. Subsequently the infection was eradicated from this country through an expensive strict detection/sacrifice program (20).

Infection by OvLV is playing an increasing role in the movement of live sheep. Serological screening of flocks is required by many countries before import licenses are granted (21). The Netherlands have recently eradicated OvLV infection in their sheep flocks, and several other countries have campaigns underway (1,12-15,22).

The risks of introducing sheep from areas with high OPP prevalence into Texas needs to be evaluated carefully. The Icelandic experience indicates that it may take several years before lentivirus infections of sheep become widespread. Once infection occurs, lentiviruses persist indefinitely in their host and replicate at different rates during the course of the lifelong infection. Subsequently, eradication of lentivirus infections is a difficult task (19). Measures to prevent the introduction of OvLV should be considered in places were the disease does not exist.

Detection of OvLV-infected animals is difficult. A positive serologic test will indicate that the animal has been infected with OvLV and should be considered a carrier. On the other hand, a negative serologic result will not necessarily mean that the animal is not infected (2). Several months can span between the time of infection and seroconversion. Techniques such as PCR to detect carrier animals are at present too expensive and elaborate to be used on a routine basis. Future research needs to address the development of inexpensive, sensitive techniques to detect OvLV-infected sheep.

Because of the present difficulties in identifying OvLV-carrier sheep and because once the infection is established it is difficult to eradicate, we recommend that replacement sheep be acquired from places that are free of OPP.

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PR-4934

Using Near Infrared Spectroscopy to Monitor Nutritional Status of Free-Ranging Goats

E.R. Leite, J.W. Stuth, R.K. Lyons, and J.P. Angerer

Summary

Calibration equations for predicting diet quality of free-ranging goats were developed using diet samples obtained with esophageal fistulated Spanish goats and correlated to near infrared spectra of feces obtained from animals sharing the same forage resource. Standard errors of calibration (SEC) and validation (SEV) of the crude protein (CP) equation were 1.12 and 1.09, respectively, which were close to the laboratory stan-

dard error (SEL) of 0.91. SEC and SEV for the digestible organic matter (DOM) equation were 2.02 and 2.06, respectively, while the SEL was 1.98. The coefficients of determination (R^2) were 0.94 and 0.93 for CP and DOM, respectively.

The statistical parameters, magnitude of the wavelengths coefficient, and the chemical relationships between the primary wavelengths and the parameters studied indicate that prediction of diet quality of free-ranging goats can be accomplished with NIRS fecal analysis to a degree of precision equivalent to conventional laboratory diet analysis. Prediction of diet quality and nutrients balance for mature nannies showed the usefulness of fecal NIRS equations for improving nutrition programs on rangelands.

Introduction

Although the number of goats in the world is large, few studies have been made on their nutritional status under free-ranging conditions. Some experts have applied results of sheep or cattle studies to goats, generally without any modification. Others have tended to exaggerate the uniqueness of the goat by considering it functionally different from other ruminants (20).

As with other animals, a limitation of nutritional research on goats is the lack of reliable or simple techniques for measuring nutrient intake (12). Early techniques available for studying the nutrition of grazing animals are characterized by relatively low precision, high labor demand, and high sensitivity to bias (16). Possibly the most important complication in estimating nutrition of free-ranging animals is that they select forage different from that available, thereby complicating the process of estimating diet quality (3, 24, 30).

Among several techniques used for evaluating the nutritional status of free-ranging animals, perhaps the use of fecal indices has the best potential for application. Sampling site selection is critical for use of esophageal fistulated animals and hand-plucking consistently underestimates diet quality (5).

Because of the labor and difficulty involved in obtaining fistula samples, considerable effort has been directed toward developing indices that predict relationships between diet and fecal parameters (9, 17, 28, 37). Most of these studies are based on direct wet chemistry analysis of feces and have yielded marginal results (17). In ruminants, this relationship is complicated by interactions involving dry matter intake, the fibrous nature of diet, microorganisms in the digestive tract, endogenous tissues, and the non-protein nitrogen compounds present in some forage species (25).

Near infrared reflectance spectroscopy (NIRS) technology, which is already being successfully used in forage analysis, offers the potential to develop a rapid, reliable, and easily used method of estimating the nutritional quality of the range animal's diet (22). Recent studies by Coleman et al. (4), Lyons and Stuth (19), and Stuth et al. (29 and 30) indicate that NIRS appears to provide equivalent or superior estimates of diet quality from fecal analysis compared with wet chemistry methods. Lyons and Stuth (18) reported success in predicting dietary protein and digestibility of cattle diets in southern and east-central Texas using NIRS technology.

The NIRS analysis method is based on the principle that each major chemical component of a sample has near infrared absorption properties that can be used to differentiate components from each other (22). Major advantages of NIRS analysis include speed, ease of sample preparation, multiple analyses performed in one operation, and non-destruction of samples (22). Disadvantages include instrument requirements, dependence on calibration procedures, complexity of choosing data treatments, and lack of sensitivity for minor constituents (22). Calibration is necessary for each component analyzed, and usually calibration is valid only for the same type of sample (22). Thus, standardization of collection and handling procedures is important.

Interest in meat-goat production is increasing in the thorn-shrub region of South Texas in response to increasing export demand from Mexico and local markets (26). Producers from other regions are also seeking new enterprises to diversify their profit centers. The intensification of meat-goat production will dictate a greater understanding of nutritional impact of grazing management on potential animal performance. The recent advances in application of NIRS technology for predicting cattle diets indicate that capability to assess the nutritional well being of meat-type goats under extensive conditions via NIRS is feasible.

The purpose of this research is to determine whether NIRS technology can be used successfully to detect nutritional status of free-ranging goats.

Materials and Methods

Field Area

To provide data for calibration of NIRS and development of a master equation for diet quality prediction for goats, two studies were conducted. The first location was at the La Copita Research Area, approximately 8 miles southwest of Alice, in South Texas (27°40′ N, 98° 12′ W). The area is characterized by dense thorn-shrub dominated by mesquite (*Prosopis juliflora*) and a complex of more than 20 shrubs, 27 grasses, and 52 forbs (8). The second location was on the Texas A&M Native Plant and Animal Conservancy, approximately 4 miles south of College Station (30°37′ N, 96°21′ W). The area is representative of the Post Oak Savannah region of Texas, being dominated by an overstory of post oak (*Quercus stellata*). Yaupon (*Ilex vomitoria*) is a dominant shrub, and the herbaceous vegetation is dominated by several forbs and grass species.

At La Copita, extrusa and fecal samples were collected from Spanish goats (60 to 70 lb) grazing six, 6-acre paddocks, reflecting three levels of available browse, replicated twice, and conducted from August 1990 to August 1991. In College Station, samples were collected from five small paddocks, each one simulating a particular kind of predominant vegetation (native grasses, evergreen shrubs, deciduous shrubs, cool-season grass, and a grassland savanna). Extrusa samples were collected from esophageally fistulated animals, and fecal samples were collected from a non-fistulated grazers.

Laboratory Analysis

Esophageal samples were analyzed for crude protein (CP) by Kjeldhal procedure (1) using the Hach system (7). Digestible organic matter (DOM) was determined by in vitro procedures using a 48-hour fermentation (31) followed by neutral detergent fiber procedure (32). Extrusa samples were used as dependent variable reference data for NIRS equation development.

Fecal samples were dried in a forced-air oven at 60°C for 48 hours. Dried samples were ground in a Udy mill to pass a 1-mm screen to reduce particle size and provide uniform particle dimension for improved precision of NIRS results (23). To stabilize moisture, ground samples were placed in a forced-air oven for 12 hours before scanning with a Pacific Scientific 4250 (19).

Equation Development

CP and DOM used as dependent variables were obtained from laboratory analysis of esophageal extrusa samples, while stored NIRS spectra from fecal samples were used as independent variable reference data for calibration equation development (19, 30). Equations were developed by modified stepwise regression (33). The stable equations were determined after the elimination of possible outliers and the data were subjected to various math treatments. For each math treatment, the best equations were identified through the consideration of several factors, which include the coefficient of determination (R^2), standard error of calibration (SEC), laboratory standard error (SEL) (14), wavelength F-statistics (34), wavelength coefficient magnitude (35), and examination of wavelengths to determine the existence of chemical relationships with the parameters being studied (14).

Nutrient Balance

Through the use of the selected equations for CP and DOM, the nutrients balance (crude protein and energy) for mature nannies from the La Copita Research Area was studied. Fecal samples were collected from goats grazing three levels of shrubby vegetation (low, moderate, and high). Nutrient status was contrasted with the NUTBAL simulation model, which reflects environmental conditions, forage availability, breed characteristics, and different physiological states of nannies (dry, open, pregnant, and lactating) (6).

Results and Discussion

Analysis to determine equations for CP and DOM were started with samples from both College Station and La Copita together, but the results were discouraging because the R-squares (R^2) were lower and the standard errors of calibration (SEC) were higher than acceptable limits.

Stratified analyses were then performed on both College Station and La Copita data sets. Results obtained with La Copita's samples were worse than when its data were analyzed together with College Station's data, while a substantial improvement was found when the College Station samples were analyzed alone.

We concluded that the multiple 15-min. extrusa samples collected in La Copita paddocks were not representative of the nutritional quality of goat diets integrated over the grazing trial. While in College Station, the animals had no more than 20 different plant species to select in the small paddocks, in La Copita they had about 100 species.

Consequently, it was decided to develop the equations using only the College Station data set and to test spectral integrity of the final equation at the La Copita site.

CP and DOM Equations

The crude protein equation was developed with a set of samples with values ranging from 4.3 to 25.1 percent CP. R^2 (0.94) (Table 1) was as high as values reported by other authors (2, 9,19), who developed their studies with cattle. Standard error of calibration (SEC = 1.12) (Table 1) was close to the laboratory standard error (SEL = 0.91), being within the acceptable limits for NIRS calibration procedures (14). These findings indicate that procedures used in sample preparation introduced little error. In general SEC for CP in this study was close to those reported by other authors (2, 10, 19).

Table 1. In vivo corrected crude protein (CP) and digestible organic matter (DOM) equations for free-ranging goats from College Station calibration set.[1]

	Calibration				Validation			
Equation	Wavel.	F	SEC	R^2	SEV (C)	R^2	Bias	Slope
CP	2305	360	1.12	0.94	1.28	0.94	0.16	1.08
	2241	229						
	2027	170						
	2174	332						
	2260	124						
DOM	2143	89	2.02	0.93	2.12	0.92	0.18	0.91
	2018	182						
	2057	111						
	2301	169						

[1]Math treatment for both equations is 2, 10, 10, 1.

The digestible organic matter equation was developed with samples ranging from 40.9 to 71.8 percent DOM. R^2 (0.93) (Table 1) was higher than values found for cattle equations by other authors. Brooks et al. (2) and Holecheck et al. (10) found, respectively, R^2 values of 0.88 and 0.84 for in vitro dry matter digestibility. Lyons and Stuth (19) reported a R^2 value of 0.80 for DOM. Standard error of calibration (SEC = 2.02) was close to values reported for digestibility estimates in other studies (2, 10, 19). SEL for DOM in this study was 1.98, indicating that the SEC is within the limits for NIRS calibration procedures.

The higher relative CP standard errors of calibration compared with those for DOM equations may be related to variations in the supply of nitrogen from rumen recycling and endogenous nitrogen (19). Standard errors of validation SEV(C) corrected for bias were 1.09 and 2.06 for CP and DOM, respectively (Table 1), indicating a high degree of precision in estimates (23). SEV(C) is obtained by using an equation developed from odd-numbered samples predicting even-numbered samples (23).

The final step for selection of NIRS equations involves examination of wavelengths to determine whether meaningful chemical relationships exist for the variables measured (14). Although wavelengths of multiterm equations are so independent that interpretation of individual wavelengths are often difficult, it has been recommended that only examination of the first two wavelengths in terms of F-statistics rank should be conducted (23, 36). However, because a tilting filter instrument was used in this study, only the primary wavelength was used for analysis, as suggested by Lyons and Stuth (19).

NIR instruments determine CP, DOM, and other components by measuring log(1/reflectance) or log(1/R), which is related to absorption (14). A higher log(1/R) value means that more radiation has been absorbed (less reflected) by the sample at that wavelength. To accentuate spectral characteristics, Hruschka (14) suggested the conversion to second derivative of log(1/R) spectra of fecal samples representative of forage quality at extremes of data set. Spectra of fecal samples representing diet quality extremes for CP and DOM in this study are illustrated in Figure 1. For the CP equation, it shows greater absorbance for the high-quality sample at the primary wavelength (2,305 nm). Norris et al. (23) and Redshaw et al. (27) associated this wavelength with neutral detergent fiber (NDF) of forage samples. Huston and Pinchak (15) describe CP as one of the components of NDF in plant cell wall, normally the less digestible portion of the plant cell, usually related to fecal components. Lyons and Stuth (19) suggested that the greater absorbance associated with feces from high-quality forage may indicate detection of microbial response to diet quality through absorbance associated with chemical bonds in undigested rumen microbial cell walls, whole

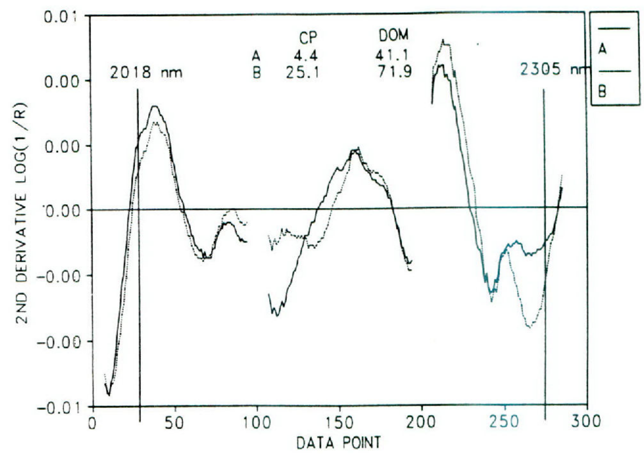

Figure 1. Comparison of second derivative log(1/R) fecal spectra associated with fermentation of low (A) and high (B) quality forages illustrating greater absorbance at most significant estimated wavelengths in the DOM equation (2,018 nm) for sample A and in the CP equation (2,305 nm) for sample B. Valleys (minima) in second derivative are analogous to peaks (maxima) in log(1/R) spectra. Gaps indicate filter changes.

microbial cells produced in the lower gastrointestinal tract, and aromatic and other by-products of microbial degradation.

For the spectral region around the primary wavelength (2,018 nm) in the DOM equation, absorbance was greater in the low-quality sample (Figure 1). This wavelength falls in the range of wavelengths related with -OH (hydroxyl) chemical bonds, which are reported to be in all starch- and cellulose-containing substances (21). This sample was collected in February 1991 in a paddock dominated by mature grass. It has been widely reported that digestibility of forages declines with maturity, which is associated with increased fiber or cell wall content (11, 13, 15).

Nutritional Balance

To gain a better perspective on usefulness of the final prediction equation, we analyzed feces from the goats grazing the paddocks representing low, moderate, and high levels of woody plant cover. Generally, goats grazing the high-woody-plant paddocks selected diets higher in CP throughout the grazing season, except in the driest periods of summer (Figure 2). Dietary crude protein fell below requirements in all paddocks during winter periods. However, the goats grazing the low-woody-cover paddocks experienced protein deficits earlier in winter (Figure 2).

Net energy of maintenance (NEm) balance was more erratic (Figure 3). However, the goats grazing the high-browse paddocks selected diets greater or equal to those of goats grazing paddocks at the other levels of woody plants. Only in the fall, when high soil moisture generated young forbs and fresh grass leaves, did the low-browse paddocks provide goats with higher DOM diets and NEm balance.

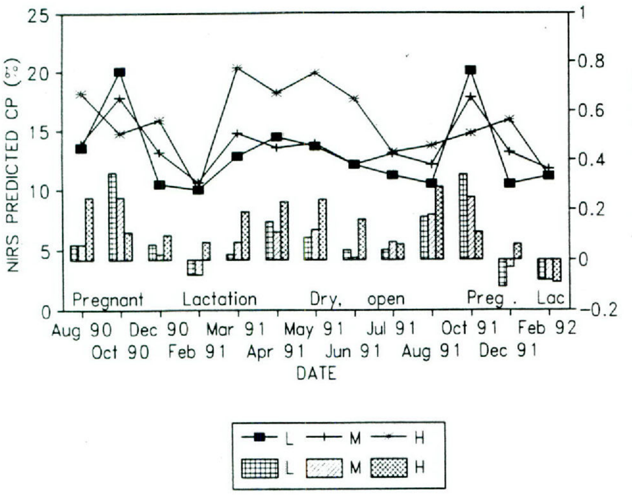

Figure 2. Effects of brush level on crude protein balance (lb/day) of nanny goats under different physiological states and varying seasonal conditions.

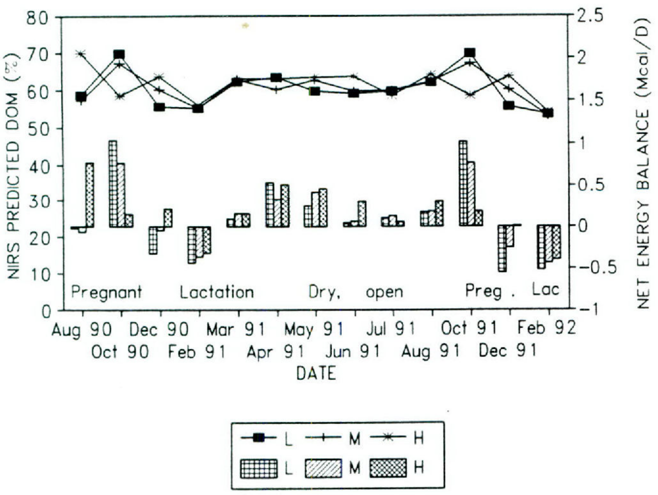

Figure 3. Effects of brush level on NEm balance (Mcal/day) of nanny goats under different physiological states and varying seasonal conditions.

Given the accelerated breeding program used in this experiment, the nannies were in a negative plane of nutrition during late pregnancy and early lactation for both kidding cycles. However, the animals were able to regain body condition for rebreeding during the latter stages of lactation and during the pre-breeding period. Strategic supplementation during winter could be assisted with NIRS technology. As indicated in this study, NIRS technology coupled with the NUTBAL decision-support model detected differences in nutritional status of goats grazing in paddocks of contrasting vegetation.

Conclusions

These studies indicate that NIRS is a viable technology for predicting diet quality of free-ranging goats. Our results show that generalized fecal NIRS calibration equations can accurately predict CP and DOM from goat diets on ranges with a wide variation in botanical composition. NIRS shows great potential as a tool to reduce time, labor, and cost inputs associated with nutritive evaluation of range animal samples, helping to establish improved programs of animal supplementation and improving production and reproduction management systems. For the first time, the ranching industry has technology that can assist nutritional management of free-ranging stock. How this technology is delivered and applied will depend on the entrepreneurial vision of the industry.

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PR-4935

Evaluating Diet Selection by Sheep

A.M.S. McFarland and M.M. Kothmann

Summary

The objective of this study was to simulate diet selection by sheep grazing on rangelands. This was done by calibrating linked forage dynamics, diet selection, and sheep production models for two sites in the Edwards Plateau region of Texas. The forage dynamics model simulated accumulation, removal, and quality for 33 different forage components representing live and dead leaf and stem for 10 different forage classes. Harvestability, preference, avoidance, and palatability parameters were associated with each forage component through the diet selection model. The sheep model was used to calculate intake and to set grazing pressure. Diet selection was adequately represented by the models on both of the sites simulated. Interaction of forage quality and availability resulted in complex diet selection responses that were strongly tied to seasonal forage growth.

Introduction

Field techniques used to evaluate the plant/animal interface generally involve a long-term commitment of time, labor, and resources and often lead to results that are difficult to interpret. To aid analysis and extend field data, forage dynamics, diet selection, and sheep production models were linked, calibrated, and validated for two sites in the Edwards Plateau region of Texas. The forage dynamics model simulates the accumulation of live biomass, aging, and senescence of live biomass, movement of dead biomass to mulch, and changes in quality of live and dead biomass (2). The sheep model simulates growth, reproduction, lactation, and fiber production (1). The diet model determines the crude protein, digestibility, and availability of dry matter selected in the sheep's diet (3).

Experimental Procedure

Field data used in the calibration were reported by Kothmann (4) for heavy- (HS) and light- (LS) stocked pastures at the Sonora Experiment Station. Esophageal-fistulated wethers were used to obtain samples to evaluate the botanical composition and crude protein (CP) content of diets at 16 evenly spaced intervals from June 1964 through May 1965. Collections were taken from four fistulated sheep for six consecutive days and pooled by sheep. Diet information was obtained by forage category (grass, forb, and browse). Each pasture contained 32.4 ha. In May 1964, the LS pasture was stocked with 13 wether sheep, and the HS pasture was stocked with 45 wether sheep. In November, the flocks were replaced with 17 wethers on the LS pasture and 50 wethers on the HS pasture.

Simulations were run for 360 days using a 1-day time-step for the forage and diet models and a 15-day time-step for the sheep model. Sheep model parameters were updated using an average diet calculated by the diet model for the previous 15 days. Input parameters for the sheep model were set according to field measurements taken before the start of the field trial and on genetic parameters suggested by Blackburn et al. (1) for Rambouillet sheep.

Forage classes simulated by the forage model included warm-season grass leaves and stems, cool-season grass leaves and stems, warm-season forb leaves and stems, cool-season forb live leaves, and plateau oak (*Quercus virginiana*) leaves, bitterweed (*Hymonoxys odorata*) whole plants (leaf and stem combined), shin oak (*Q. sinuata*) leaves, juniper (*Juniperus* sp.) leaves, acorns (*Quercus* sp.), and pricklypear (*Opuntia* sp.) fruits. Simulation and validation results of forage biomass and quality dynamics for these classes were presented by Spangler (7).

User inputs for the diet selection model included values for harvestability, palatability, and avoidance for each forage component. Harvestability was defined by a modified Michaelis-Menten function, which increasingly restricted grazing with decreasing forage availability (3). FMAX represents the forage quantity (kg/ha) above which forage is freely available to the grazing animal and below which intake is restricted and defines the harvestability equation. Values for FMAX were fit for each forage component using iterative simulation exercises on the LS pasture (5). These same values were then used for simulation runs on the HS pasture.

Palatability represents an upper limit on the proportion of the desired diet that can come from any one forage component (0.0-1.0 index). A palatability limitation of 0.04 was set on bitterweed based on poisonous plant research by Pfeiffer and Calhoun (6) and Ueckert and Calhoun (8). Avoidance represents the physical and chemical plant characteristics that reduce the relative desirability of forage (0.0-1.0 index). Avoidance values of 0.001, 0.001, and 0.1 were set for bitterweed, juniper, and pricklypear fruits, respectively, to indicate high avoidance. All other forage components were given an avoidance value of 1.0.

To evaluate the simulation results, a 95 percent confidence interval was placed around the following field measurements and compared with simulated output: diet composition, crude protein (CP) fraction of the diet, wether weights, and fleece weights.

Results and Discussion

A comparison of the simulated output for diet composition with field data for grass, forb, and browse is shown in Figure 1 for the two sites. A good fit between the measured and simulated diets was obtained for grass on the LS pasture (Figure 1a). The fit between simulated and field data for diet composition of forbs showed more divergence than for grass (Figure 1b). Browse showed a fairly good fit between field and simulated data, although simulated diets in August, November, and February were not matched by the field data (Figure 1c). Field notes did indicate that plateau oak was the major browse species in the diet during these periods, which corresponded with simulated output.

As with the LS pasture, a fairly good fit between the simulated and field data occurred for grass on the HS pasture (Figure 1d). Simulated forb composition of the diets failed to match field data at several points (Figure 1e). The most notable were in September, October, March, and April, which corresponded with transition period for the initiation and cessation of forb growth. Browse, in general, showed a good fit to simulated output except in January and April (Figure 1f). The wide confidence intervals on the field data indicate a large amount of variability in the diets selected by individual animals.

Simulated crude protein followed the same general trends indicated by the field data (Figure 2). Annual CP values of the LS pasture averaged 15 percent from the simulation using 15-day output and 15 percent from field data. Annual CP values of the HS pasture averaged 11 percent from the simulation and 12 percent from field data. The relatively low simulated CP values during the fall and winter reflect the differences in forb content between the simulated and field diets.

Sheep weights generally increased as expected for growing wethers on both pastures (Figure 3). Weight gains on the HS pasture were lower than on the LS pasture, which corresponded with the lower availabil-

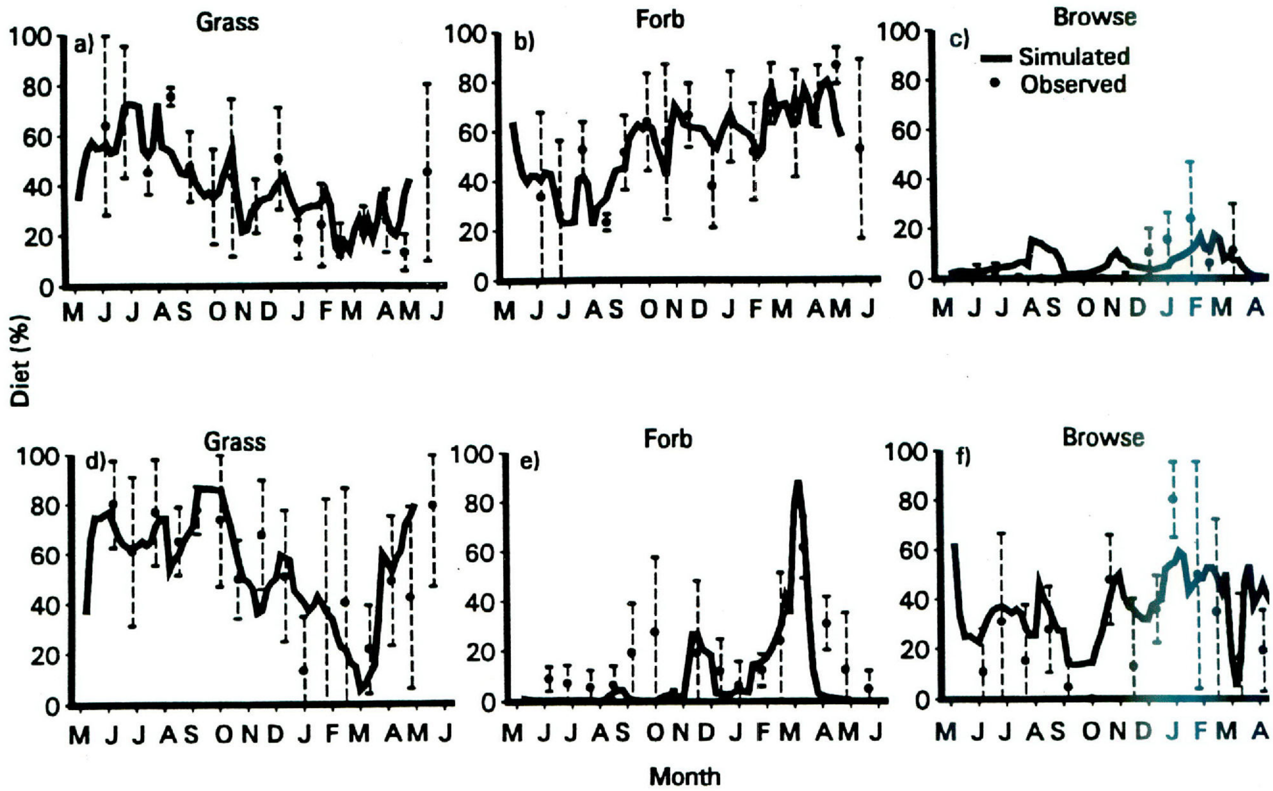

Figure 1. a), b), and c) present observed and simulated diet composition for the lightly stocked pasture, and d), e), and f) present observed and simulated diet composition for the heavily stocked pasture. Vertical bars represent 95 percent confidence intervals on the field data.

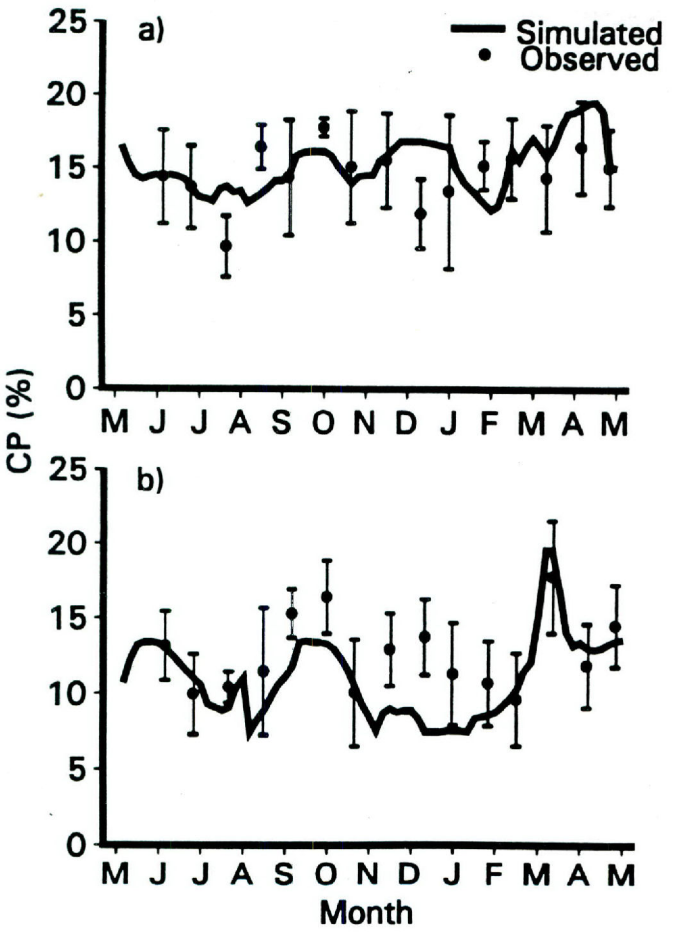

Figure 2. Simulated and observed diet crude protein (CP) for the a) lightly stocked and b) heavily stocked pastures. Vertical bars represent 95 percent confidence intervals on the field data.

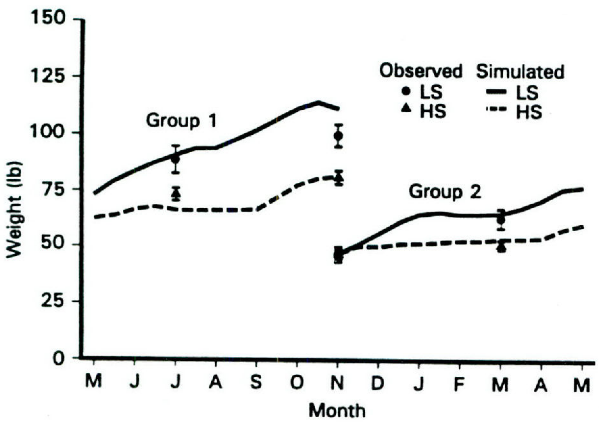

Figure 3. Simulated and observed wether weights for the lightly stocked (LS) and heavily stocked (HS) pastures. Vertical bars represent 95 percent confidence intervals on the field data.

ity of forage on the HS pasture. Fleece weights fit well within the 95 percent confidence limits placed on the field data, assuming a grease yield of 50 percent (Figure 4).

The simulations emphasized the importance of understanding the seasonal biomass dynamics of each

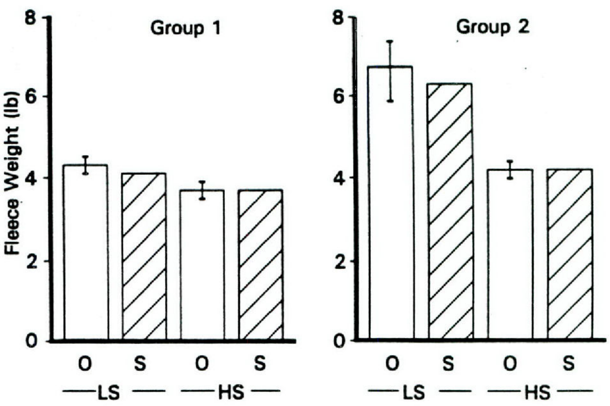

Figure 4. Simulated (S) and observed (O) fleece weights for the lightly stocked (LS) and heavily stocked (HS) pastures. Vertical bars represent 95 percent confidence intervals on the field data.

forage class in evaluating diet selection. Diet selection responded greatly to the seasonal growth patterns of warm- and cool-season plants. This was particularly true for forbs. Forb content in simulated diets followed the same general trends as in the field data, but the magnitude and timing of dietary shifts varied. These differences were generally associated with the timing and magnitude of shifts in forage biomass and quality, i.e., the initiation and cessation of growth.

Evaluating diet selection in a range environment is difficult because of the complexity of the system. Species vary in quality and availability throughout the grazing season, so no one measurement can be identified as the key to understanding diet selection. The linked forage, diet, and sheep models provide a framework from which many different diet selection hypotheses may be tested (5). Continued use of these models at the research sites will provide a better understanding of the factors affecting diet selection and animal production on the Edwards Plateau.

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PR-4936

Diet Overlap among White-Tailed Deer, Spanish Goats, Angora Goats, and Sheep in the Edwards Plateau Region

Lisa C. Bradley, Fred C. Bryant, and Charles A. Taylor, Jr.

Summary

Diet overlap among white-tailed deer, Spanish goats, Angora goats, and sheep was determined monthly on excellent condition range and poor condition range of the Texas Agricultural Experiment Station, Sonora, Sutton County, Texas, from August 1975 through July 1976. We suggest that the long-term mismanagement of livestock (overstocking and continuous grazing of cattle, sheep, and goats), which reduced herbaceous diversity and biomass on poor condition range, and root-plowing, which reduced browse diversity and biomass on excellent condition range, had a more important influence on deer diets and nutrition than livestock competition. Competition between deer and livestock appeared to be light and probably had little effect on either deer or livestock performance.

Introduction

For the diverse vegetation of the Edwards Plateau, it is expected that an optimal mix of grazing and browsing animals, each with a different set of forage preferences, will utilize the available forage biomass more efficiently than will a single species. Ranch productivity and rangeland stability should be increased by mixed species grazing.

Study Area and Methods

Pasture 10 was characterized by abundant forb and grass cover and limited browse. This pasture was considered to be in excellent range condition. Pasture 4 was dominated by browse and was considered to be in poor condition.

Diets of white-tailed deer were determined by the feeding minutes technique (1), which involved observing two tame deer and recording feeding seconds for each plant species consumed. Livestock diets were determined by microhistological analyses of extrusa samples from esophageally fistulated animals. Kulzinski's coefficient of similarity formula (6) was used to determine monthly diet overlap values for each animal combination in each pasture. Overlap values were determined for total diets and for each forage class.

Results and Discussion

Diet overlap values for Pasture 10 are presented in Tables 1 to 6, and for Pasture 4 in Tables 7 to 9. Overlap values can be compared between species combinations within a pasture, between pastures within a species combination, and between months within a species combination and pasture to evaluate the effects of diet

Table 1. Diet similarity (%), by forage class and total diet, between white-tailed deer and Angora goats in Pasture 10 (excellent condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	12.0	3.3	5.5	43.5	34.7	7.7	13.5	40.7	23.6	5.9	4.0	47.6	20.2
Forbs	2.5	2.9	38.1	24.0	8.0	2.6	1.6	36.8	30.9	22.6	22.5	17.8	17.5
Browse	77.3	61.8	75.1	84.0	97.1	89.5	90.0	19.8	66.8	51.7	63.8	46.3	68.6
Total diet	39.2	38.3	41.7	67.0	62.7	52.1	28.2	40.9	28.5	17.8	33.3	28.6	39.9

Table 2. Diet similarity (%), by forage class and total diet, between white-tailed deer and Spanish goats in Pasture 10 (excellent condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	3.3	3.3	3.0	39.8	37.4	31.0	24.0	47.7	30.6	25.8	27.5	53.8	27.3
Forbs	2.7	8.2	0.8	0.0	8.0	7.4	1.6	26.0	26.1	19.4	24.8	32.8	13.2
Browse	80.0	61.9	74.7	84.0	97.1	89.5	90.0	33.4	63.7	56.4	61.8	38.5	69.3
Total diet	38.7	41.2	49.7	60.6	54.7	53.9	57.2	30.5	40.8	25.4	38.5	34.7	43.8

Table 3. Diet similarity (%), by forage and total diet, between white-tailed deer and sheep in Pasture 10 (excellent condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	3.2	3.3	3.0	42.0	22.7	32.0	39.4	55.0	19.3	12.5	13.5	38.7	23.7
Forbs	2.7	10.4	27.7	33.7	8.0	28.3	1.6	41.8	20.7	25.7	35.6	36.1	22.7
Browse	77.3	59.2	74.7	84.0	97.1	89.5	90.0	45.4	59.6	51.7	59.2	39.2	68.9
Total diet	18.0	14.7	27.3	58.0	71.9	29.0	18.9	22.2	16.4	24.0	36.1	36.1	31.1

Table 4. Diet similarity (%), by forage class and total diet, between Angora goats and sheep in Pasture 10 (excellent condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	63.3	73.1	69.0	56.0	30.0	65.4	62.7	77.1	62.5	68.2	25.9	86.6	61.7
Forbs	38.9	84.4	26.1	20.0	87.4	72.1	50.0	48.4	42.3	28.9	69.9	40.8	50.8
Browse	100.0	97.4	94.3	100.0	100.0	100.0	100.0	62.6	87.4	100.0	86.1	92.9	93.4
Total diet	50.1	67.1	63.6	70.1	79.8	67.2	45.9	53.6	53.3	42.5	54.7	66.3	59.5

Table 5. Diet similarity (%), by forage class and total diet, between Spanish goats and sheep in Pasture 10 (excellent condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	69.0	45.2	81.2	66.7	43.3	81.0	69.0	68.9	66.5	64.0	47.0	85.9	61.7
Forbs	20.8	88.1	17.5	0.0	93.4	76.9	50.0	63.0	37.2	28.9	69.1	46.6	49.3
Browse	97.3	94.8	94.3	100.0	100.0	100.0	100.0	70.8	95.9	95.3	86.1	89.4	93.7
Total diet	48.8	55.6	63.1	76.5	74.6	69.5	40.6	46.6	48.7	45.4	55.5	73.0	58.2

Table 6. Diet similarity (%), by forage class and total diet, between Angora goats and Spanish goats in Pasture 10 (excellent condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	68.8	35.9	69.6	70.7	65.4	69.2	65.0	72.9	75.0	58.3	22.8	87.4	63.3
Forbs	82.0	86.7	0.0	0.0	94.0	90.3	100.0	47.0	77.8	71.8	65.8	66.8	65.2
Browse	97.3	97.4	96.5	100.0	100.0	100.0	100.0	83.7	87.4	95.3	92.0	85.4	94.6
Total diet	82.8	77.4	67.9	79.1	85.1	90.1	70.6	65.0	67.4	77.3	58.5	81.4	75.2

selectivity, forage availability, season, and grazing systems on diet similarity and potential competition between species.

Diets were most similar within the browse component in Pasture 10. Plateau oak (*Quercus virginiana* var. *fusiformis*) dominated available browse vegetation in this pasture and thus dominated the browse component of all diets. This resulted in high similarity values year-round, indicating that deer and livestock (especially goats) may have been competing for browse in Pasture 10. Bryant et al. (2) suggested that Spanish goats were more serious competitors with deer for browse than were Angora goats. Results of our analyses do not support this hypothesis; competition between deer and goats for browse in Pasture 10 appeared to be similar regardless of the goat species. In Pasture 4, browse availability and diversity were greater than in Pasture 10. This resulted in lower diet similarity values, because deer and goats used a greater variety of browse species. Deer, Angora goat, and Spanish goat diets included plateau oak year-round, Vasey shin oak (*Quercus pungens* var. *vaseyana*) during spring and summer, and juniper (*Juniperus* spp.) during winter. Deer and Spanish goats also included Texas persimmon (*Diospyros texana*) in their diets during the spring.

Table 7. Diet similarity (%), by forage class and total diet, between white-tailed deer and Angora goats in Pasture 4 (poor condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	-	0.0	0.0	16.3	10.3	6.9	0.0	0.0	0.0	20.3	12.1	13.3	7.2
Forbs	-	0.0	18.9	0.0	0.0	0.0	0.0	0.0	0.0	21.0	22.1	0.0	5.6
Browse	-	27.9	54.7	49.6	45.7	31.5	61.6	61.5	85.5	77.0	64.4	58.1	56.1
Total diet	-	27.3	44.1	45.2	42.4	31.4	53.1	54.8	61.5	61.1	53.1	45.4	47.2

Table 8. Diet similarity (%), by forage class and total diet, between white-tailed deer and Spanish goats in Pasture 4 (poor condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	-	0.0	0.0	10.1	7.2	5.0	40.4	0.0	-	9.2	8.6	0.0	8.1
Forbs	-	0.0	0.0	29.4	0.0	0.0	0.0	0.0	-	0.0	11.8	0.6	4.2
Browse	-	32.7	54.5	52.4	38.2	31.5	61.6	37.7	-	56.7	46.0	48.4	46.0
Total diet	-	30.3	52.4	47.8	35.2	31.4	60.6	34.0	-	35.4	42.3	32.9	40.2

Table 9. Diet similarity (%), by forage class and total diet, between Angora goats and Spanish goats in Pasture 4 (poor condition).

	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	x
Grasses	-	61.5	53.2	17.7	44.1	85.6	59.7	62.2	-	66.2	12.1	18.3	48.1
Forbs	-	0.0	0.0	16.7	0.0	50.0	89.2	25.0	-	0.0	19.7	0.0	20.1
Browse	-	60.9	85.7	96.9	92.5	94.0	90.6	56.4	-	59.8	81.6	79.3	79.8
Total diet	-	47.7	72.8	73.2	81.6	87.2	84.7	53.4	-	56.8	62.3	66.5	68.6

Overlap within the forb component of deer and livestock diets was slight in both pastures. In Pasture 10, the forb component of livestock diets was dominated by Mexican sagewort (*Artemisia ludoviciana*), a species consumed in only trace amounts by deer. Slight competition was indicated between deer and livestock, particularly sheep, for upright prairie coneflower (*Ratibida columnaris*) during the winter. During late spring and summer, competition was indicated for mallow (*Abutilon* sp.) and orange zexmenia (*Zexmenia hispida*). Sheep competed with deer more directly than did either goat species. Although Angora goats consumed more total forbs than did Spanish goats, Spanish goats consumed more of the forb species preferred by deer, such as mallow and orange zexmenia. In Pasture 4, diet similarity within the forb component was low because forb availability was extremely limited. In general, deer did not consume forbs in this pasture except during July when spreading sida (*Sida filicaulis*) increased in availability because of abundant rainfall and mild temperatures; goats in Pasture 4 did not consume spreading sida during July.

Within the grass component, overlap between deer and livestock was relatively low and stable in Pasture 10. Although grass consumption by all the study animals increased during spring and during a re-growth period in July, deer and livestock rarely consumed the same species. Overlap in grass use between the livestock species, however, was consistently high in Pasture 10. Goats and sheep shared grass species such as Texas cupgrass (*Eriochloa sericea*), Texas wintergrass (*Stipa leucotricha*), sideoats grama (*Bouteloua curtipendula*), and bluestem (*Bothriochloa* spp.). In Pasture 4, availability of most grass species was extremely low, limiting use of grasses by deer and livestock. Grass species preferred by deer were especially lacking in this pasture. Sedges were the only important grass or grass-like species in deer diets in Pasture 4. Sedges were a minor component of livestock diets, but slight competition between deer and goats for sedges may have occurred during winter. Spanish goats appeared to be more successful than Angora goats in competing for grasses in Pasture 4 because their diets contained greater quantities of the more preferred species such as Texas cupgrass and bluestems.

Numerous researchers have reported the importance of diversity in deer diets (3,5,7). The consumption by deer of many species in small amounts, rather than a limited number of species in large amounts, can limit competition between deer and livestock (7). In our study, the diversity and abundance of herbaceous forages in Pasture 10 and browse forages in Pasture 4 allowed the study animals to forage selectively and express their dietary preferences. Under these conditions, the deer and livestock generally selected different species, and overlap was minimal. Thus, a mixed-species grazing strategy apparently would allow for the most efficient use of the range resources, as suggested by Bryant et al. (2), when range resources are diverse and abundant in all forage classes.

Overall, deer and livestock diets in our study were most similar for browse. This component of the vegetation is abundant on the Edwards Plateau, but can be limiting to deer production where browse diversity is low. Forbs are nutritionally valuable, highly preferred, but seasonally limited in availability in this region. Our study indicated that when diversity is sufficient to allow for selection of preferred species, deer and livestock rarely consume the same forb species. Immature grasses are palatable and are excellent sources of energy for deer and livestock when available, primarily during grazing deferment periods, but deer and livestock prefer different grass species.

Dietary overlap between deer and livestock appeared to be light in this study and probably had little direct effect on deer or livestock performance. Differences in site conditions, however, had substantial effects on deer diets. Traditional thinking has held that poor to fair condition range, usually characterized by an abundance of browse species, is more favorable to white-tailed deer than is excellent condition range, which is usually dominated by grasses (4). Our results suggest that excellent condition pastures can provide optimal deer-foraging habitat, with a desirable diversity of forbs and grasses. However, the excellent condition pasture in this study lacked sufficient browse diversity for deer. Pasture 4 provided a desirable level of browse diversity but was lacking in the grass and forb components essential for good deer nutrition. Deer need high floral diversity in all forage classes to minimize competition with livestock and maximize nutrient and energy intake. Thus, good deer habitat in the Edwards Plateau region would best be characterized by an interspersion of herbaceous feeding sites high in grass and forb diversity with blocks of woody cover nearby that are high in browse species diversity.

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PR-4937

Diets of White-Tailed Deer, Spanish Goats, Angora Goats, and Sheep in the Edwards Plateau Region

Lisa C. Bradley, Fred C. Bryant, and Charles A. Taylor, Jr.

Summary

Diets of white-tailed deer, Spanish goats, and Angora goats were determined monthly on two pastures (Pasture 10, representative of excellent condition range and Pasture 4, representative of poor condition range) of the Texas Agricultural Experiment Station, Sonora, Sutton County, Texas, from August 1975 through July 1976. Diets of sheep were determined also on Pasture 10. Differences in floral diversity between the two pastures affected deer diets to a greater degree than livestock diets. Deer diets in the less diverse Pasture 4 were only half as rich (variety of plants in the diet) as deer diets in Pasture 10. Angora and Spanish goat diet richness was approximately the same in both pastures. These data suggest that livestock are more tolerant than deer of poor range condition.

Introduction

The Edwards Plateau supports one of the largest white-tailed deer (*Odocoileus virginianus* L.) concentrations in the world, and many landowners in this region derive substantial income from the sale of hunting privileges. However, livestock production is generally the largest source of ranch income. Consequently, dietary interrelationships between livestock and deer are a recurring subject for discussion in western Texas.

Experimental Procedures

Pastures 10 and 4 both were located within Low Stony Hill range sites with Tarrant stony clay soils. Both pastures were grazed during the study by a combination of cattle, sheep, and Angora goats in a 2:1:1 ratio. However, the two pastures differed markedly in management history and forage availability and composition. From 1948 to 1970, Pasture 10 received light continuous grazing (16 animal units [au]/sec). In 1970, it was root-plowed and seeded with both introduced and native grass species. Stocking rate was subsequently increased to 40 au/sec, and the Merrill grazing system (four pasture, three herd, 12-mo grazing followed by 4-mo rest) was applied. The stocking rate was increased to 48 au/sec in 1974. This pasture was considered to be in excellent range condition. Pasture 4 was continuously grazed yearlong at 48 au/sec from 1948 through the study period. This pasture received no improvements and was considered to be in poor condition.

Availability of grasses and forbs in the two pastures were determined monthly using a modification of a double sampling technique where vegetative cover was visually estimated and then random units of the vegetation were clipped and weighed (5,6,7). Browse standing crop was estimated at five periods during the study. Browse availability in Pasture 10 was estimated by multiplying mean weight per plant by plants per ha (3). In Pasture 4, browse availability was determined by using the same double sampling technique used for grass and forbs (7). Diversity (8) of forage within each forage class (browse, forb, grass) was determined as an overall mean for each of the two pastures (Table 1).

Botanical composition of white-tailed deer diets was estimated by observing two tame deer (aged 4 and 5 months at the start of the study) and recording feeding seconds for each plant species consumed during a 2-hour morning observation period 5 consecutive days each month (1). Composition of livestock diets was determined from microhistological analyses of extrusa samples obtained from esophageal cannulae. Livestock were grazed in the afternoons of the same 5 days the deer were grazed each month.

Table 1. Diversity (index) of forage within each forage class on Pastures 10 and 4.

	Pasture 10	Pasture 4
Browse	0.22	0.77
Forbs	2.21	1.89
Grass	2.01	1.28

Results and Discussion

Grass standing crop averaged three times greater in Pasture 10 than in Pasture 4. Forb standing crop averaged six times greater in Pasture 10 than in Pasture 4. Browse standing crop averaged three times greater in Pasture 4 than in Pasture 10 (4).

Table 2 presents the monthly and annual diets for deer, Angora goats, Spanish goats, and sheep, respectively, in Pasture 10 and the monthly and annual diets for deer, Angora goats, and Spanish goats, respectively, in Pasture 4.

In Pasture 10, 11 species composed 83.6 percent of annual deer diets; 10 species composed 87.1 percent of annual Angora goat diets; 10 species composed 89.3 percent of annual Spanish goat diets; and 13 species composed 84.4 percent of annual sheep diets. Of these species, the only species common to deer and livestock annual diets were plateau oak (*Quercus virginiana* var. *fusiformis*), mallow (*Abutilon* sp.), and orange zexmenia (*Zexmenia hispida*), and, to a lesser degree, Johnsongrass (*Sorghum halepense*) and upright prairie coneflower (*Ratibida columnaris*).

Browse and forb consumption by deer in Pasture 10 was inversely related; highest browse consumption was during winter, and highest forb consumption during summer. Deer use of browse was negatively correlated with forb availability ($r = -0.79$, $P < 0.01$), whereas use of forbs was positively correlated with forb availability ($r = 0.81$, $P < 0.01$). This indicated that deer preferred forbs over browse, but were forced to use browse when forb availability was low. Grass consumption by deer was relatively stable except for a peak in July (22 percent) in response to regrowth of grasses following a period of heavy rain and grazing deferment. Angora goats consumed less browse, similar proportions of forbs, and more grasses than did deer. Spanish goats in this pasture consumed slightly more browse than did Angora goats, but diets were similar between the two goat species. Annually, sheep diets in Pasture 10 were dominated by grasses and contained more grasses and less browse than diets of the other herbivores. Browse and forb consumption were inversely related in sheep diets. In Pasture 4, 5 species represented 94.7 percent of annual deer diets, 10 species represented 89.0 percent of annual Angora goat diets; and 7 species composed 83.6 percent of annual Spanish goat diets. Of these species, plateau oak, Vasey shin oak (*Quercus pungens* var. *vaseyana*), and juniper (*Juniperus* sp.) were shared by deer and livestock.

Browse dominated the diets of all the study animals in Pasture 4 and was greatest in deer diets. Goat diets in this pasture contained more grasses and less browse than did deer diets. Both deer and livestock diets contained few forbs in this pasture because of limited availability.

Table 2. Diets (percent composition) of white-tailed deer, Angora goats, Spanish goats, and sheep.

Animal	Pasture	Forage type	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	X
Deer	10	Grasses	1.9	6.1	4.7	7.6	5.2	0.4	6.3	10.7	6.2	11.8	5.0	22.4	7.4
Deer	10	Forbs	40.0	32.9	23.6	17.2	8.8	3.8	6.1	15.8	38.0	70.5	58.7	64.0	31.6
Deer	10	Browse	58.1	61.0	71.7	75.2	86.0	95.8	87.4	73.6	55.9	17.6	36.0	13.8	61.0
Ang goat	10	Grasses	37.3	28.0	52.0	33.7	12.7	23.3	48.9	36.6	33.2	26.4	25.1	56.1	34.4
Ang goat	10	Forbs	26.0	34.0	10.5	8.0	25.4	25.0	27.9	34.1	51.5	44.1	45.3	26.7	29.9
Ang goat	10	Browse	36.2	38.0	37.3	58.1	61.9	51.8	23.3	28.7	15.1	30.0	29.6	17.0	35.6
Sp goat	10	Grasses	35.6	9.6	41.8	43.4	24.6	18.7	27.7	26.3	33.8	28.1	21.7	61.7	31.1
Sp goat	10	Forbs	27.9	44.5	8.6	1.7	23.3	28.9	20.0	29.8	37.4	42.2	36.8	21.3	26.9
Sp goat	10	Browse	36.6	45.8	49.4	55.0	52.1	52.2	52.3	44.1	29.1	29.6	41.7	16.8	42.1
Sheep	10	Grasses	55.2	46.5	52.4	42.9	18.0	25.0	83.9	71.0	47.6	59.2	37.4	73.2	51.0
Sheep	10	Forbs	29.2	43.3	26.9	9.2	14.3	48.8	2.8	19.3	47.6	30.1	41.6	21.2	27.9
Sheep	10	Browse	15.4	10.1	21.0	47.7	67.9	26.1	13.0	9.1	5.4	10.1	20.2	5.8	21.0
Deer	4	Grasses	-	0.0	0.0	8.9	3.5	0.3	1.6	0.3	0.0	0.1	2.3	4.5	2.0
Deer	4	Forbs	-	2.2	1.3	1.7	2.6	0.8	2.4	6.7	3.2	2.3	7.6	31.3	5.6
Deer	4	Browse	-	97.9	98.7	89.5	94.0	98.9	96.1	93.0	96.7	97.5	90.0	63.9	92.4
Ang goat	4	Grasses	-	12.0	35.1	4.9	9.7	13.0	8.6	21.8	31.1	29.1	9.9	17.1	17.5
Ang goat	4	Forbs	-	7.9	5.3	4.8	2.0	1.8	12.9	7.9	3.2	8.1	17.8	0.0	6.2
Ang goat	4	Browse	-	80.1	59.6	90.3	88.3	85.2	78.5	70.3	65.7	62.8	72.3	82.9	75.8
Sp goat	4	Grasses	-	36.5	32.3	23.2	25.0	17.9	5.7	13.0	-	59.5	13.9	22.4	24.9
Sp goat	4	Forbs	-	1.0	0.0	4.0	0.0	6.0	3.5	5.6	-	2.6	6.1	8.0	3.7
Sp goat	4	Browse	-	62.5	67.7	72.8	75.0	76.1	90.8	81.4	-	37.9	80.0	69.6	71.4

- No data collected.

Differences in floral diversity between the two pastures affected deer diets to a greater degree than livestock diets. Including species occurring in trace amounts, deer diets in Pasture 10 over the 1-year study period were composed of 72 species; 13 grasses, 46 forbs, and 13 browse species. In Pasture 4, deer diets were composed of only 34 species; 5 grasses, 21 forbs, and 8 browse species. Deer diets in the less diverse Pasture 4 were only half as rich as deer diets in Pasture 10. In contrast, Angora goat diets in Pasture 10 were represented by 44 species; 17 grasses, 22 forbs, and 5 browse species, whereas Angora goat diets in Pasture 4 were represented by 39 species; 16 grasses, 14 forbs, and 9 browse species. Thus, Angora goat diet richness was virtually the same in two pastures that differed greatly in forage composition, availability, and diversity. Spanish goat diets exhibited the same trend as Angora goat diets in the two pastures. Thus, differing site conditions influenced greatly white-tailed deer diets while having relatively little influence on livestock diets. This suggests that livestock are more tolerant than deer of poor range conditions.

These data are useful for identifying key forage species in deer, goat, and sheep diets under different range site condition classes. The diversity and abundance of forages, particularly grasses and forbs, in Pasture 10 allowed the study animals to express their dietary preferences, while the lack of diversity in Pasture 4 forced the study animals to consume less preferred species.

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Top Removal and Fertilization of Lotebush: Effects on Browse Yield, Quality, and Utilization by Angora Goats

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Summary

Mature lotebush (*Ziziphus obtusifolia*) plants are valuable for wildlife cover, but the value of these thorny shrubs for browse decreases with plant maturity. Research was conducted during 1990 and 1991 to determine the effects of mechanical removal of lotebush top growth alone or with fertilization on browse yields, forage quality, and utilization by Angora goats. Fertilization with nitrogen (N) at 100 lb/acre, phosphorus (P) at 100 lb/acre, or N at 100 lb/acre + P at 100 lb/acre did not affect the yield, crude protein content, in vitro digestibility, or utilization of lotebush regrowth by Angora goats. Angora goats utilized 80 to 100 percent of the regrowth sprouts and grazed the sprouts to a 3-inch stubble height. Crude protein contents of lotebush resprouts ranged from 17 to 20 percent, and in vitro dry matter digestibility ranged from 56 to 66 percent. Yield of lotebush regrowth the first growing season after top removal in an area with 3,800 plants/acre was estimated at 500 lb/acre.

Introduction

Lotebush (*Ziziphus obtusifolia*), a thorny shrub that occurs on rangelands in Texas, Oklahoma, New Mexico, Arizona, and Mexico, has both positive and negative values to ranchers and resource managers. The shrubs are considered competitive with the understory of herbaceous forage plants. Herbaceous plants were absent beneath the canopies of mature lotebush plants in a northern Texas study (5). Lotebush populations often increase and become primary brush problems following control or suppression of overstory brush species.

Lotebush, however, is recognized as important for wildlife cover (3) and as food for wildlife and livestock. Lotebush was a major food of Angora goats in the western Edwards Plateau (2) and of Spanish goats (9) and white-tailed deer (4) in the South Texas Plains. Mature lotebush was a minor food item of sheep (Rambouillet, Karakul, and Barbado breeds) and goats (Spanish and Angora breeds) in the Edwards Plateau, whereas only Spanish goats browsed the mature shrubs in the southern Rolling Plains (8).

Considerable evidence shows that the browse value of lotebush can be increased dramatically by brush control methods that remove the crowns of mature plants and that stimulate resprouting from the plant crowns and/or roots. Spanish goats browsed almost 90 percent of the regrowth stems of lotebush plants during the first growing season after a prescribed fire that burned off the mature stems (7). Preference values and forage ratings of lotebush for white-tailed deer and cattle were greatest the first year following mechanical top removal, but declined rapidly the second and third year in a southern Texas study (6).

The objective of this study was to determine the effects of mechanical top removal and top removal plus fertilizer on lotebush yields, forage quality, and utilization by Angora goats in the southern Rolling Plains.

Experimental Procedure

1990 experiment. The stems of 120 lotebush plants, with regrowth of 20 to 40 inches tall, in an 18-acre pasture in northern Tom Green County that had been burned in 1988, were cut 1 inch above the soil surface on February 1, 1990. Dense stands of lotebush dominated about one-third of the pasture. Fertilizer treatments applied March 13, 1990, within 36 inches of the base of each plant included nitrogen (N) at 100 lb/acre, phosphorus (P) at 100 lb/acre, and N at 100 lb/acre + P at 100 lb/acre, and an unfertilized control.

The experiment was a randomized complete block design with 3 replications of each treatment and 10 plants in each replication. Grazing exclosures were placed around three lotebush plants within each treatment replication. Angora does and kids were moved to the pasture when lotebush regrowth was about 12 inches tall, then removed when most of the regrowth had been grazed during three grazing periods in 1990 (Table 1). Utilization (percentage of twigs browsed and browsed canopy height) was estimated after each browsing period. Percentage of twigs browsed was visually esti-

Table 1. Grazing periods and stocking rates in lotebush utilization experiments during 1990 and 1991.

Period	Dates	Goat days/acre[1]
1990		
1	April 27 - May 15	74
2	June 13 - June 25	79
3	August 9 - August 31	117
1991		
1	May 28 - June 17	108
2	July 22 - August 7	92

[1]One Angora doe or two kids were considered one goat unit in calculating goat days/acre.

mated, and canopy height was measured from ground level to the height the majority of the twigs that had been browsed. Caged plants were clipped to the same height as the browsed plants after each grazing period, and the browse was dried at 100°F, weighed, and ground to pass a 1-mm screen. Crude protein (CP) of the browse was estimated by the Kjeldahl procedure (1), and dry matter digestibility (IVDMD) was estimated in vitro by a two-stage process (10).

1991 experiment. Lotebush plants within four 10- by 30-foot plots in the 18-acre pasture were counted and classified in height categories of <2, 2 to 4, and >4 feet, then cut 1 inch above the soil surface on April 12, 1991. Grazing exclosures were placed around four plants in each plot. Angora does and kids were grazed in the pasture during two periods in the summer of 1991 (Table 1). Utilization was estimated on 10 randomly selected plants in each plot after each browsing period, and the caged plants were harvested to the average height of the grazed lotebush. Grazing exclosures were placed on different plants before the second grazing period. Regrowth on the caged lotebush plants was harvested and analyzed as in the 1990 experiment.

Results and Discussion

Angora goats readily utilized lotebush regrowth in all fertilizer treatments during each grazing period in 1990 (Table 2). Highest utilization was in June, when all the lotebush twigs were browsed. Lowest utilization was in May, when utilization averaged 80 percent over all treatments. These utilization values are similar to those reported for Spanish goats grazing burned lotebush (7). Goats reduced lotebush canopy heights to about 3 inches during each browsing period. Crude protein contents of lotebush regrowth averaged 20 percent in May 1990 and 18 percent in June 1990. In vitro dry matter digestibility averaged 64 percent in May and 63 percent in June. Average browse yields were 27, 24, and 4 g/plant (0.9, 0.8, and 0.1 oz/plant) for the three grazing periods in 1990, respectively. Fertilizer treatments did not affect utilization, yield, CP, or IVDMD of lotebush (Table 2). Frequent observations during each grazing trial did not reveal preferential grazing among the fertilizer treatments although the heavy stocking rates utilized may have limited the potential for selective grazing.

Table 2. Utilization, heights, yields, crude protein (CP), and in vitro dry matter digestibility (IVDMD) of lotebush regrowth at the end of three grazing periods following top removal on February 1, 1990, and fertilizing on March 13, 1990, at Carlsbad, Texas. Fertilizer treatments did not produce significant differences at the 0.05 level of significance.

Fertilizer treatment	Utilization: twigs browsed	Utilization: canopy height	Caged plants: canopy height	Caged plants: yield	Caged plants: CP	Caged plants: IVDMD
	%	inches	inches	g/plant	%	%
Grazing period 1						
Control	84	2	—[1]	23	20	66
Nitrogen (N)	78	3	—	28	19	64
Phosphorus (P)	77	2	—	29	20	66
N + P	78	2	—	26	20	62
Grazing period 2						
Control	100	2	5	14	17	61
Nitrogen (N)	100	3	5	30	18	66
Phosphorus (P)	100	3	5	30	18	64
N + P	100	3	5	21	17	63
Grazing period 3						
Control	91	3	3	2	—[2]	—
Nitrogen (N)	85	4	4	5	—	—
Phosphorus (P)	89	3	4	5	—	—
N + P	86	3	4	4	—	—

[1]Data not collected.
[2]Yields insufficient for laboratory analyses.

Lotebush density averaged about 3,800 plants/acre (range 2,904 to 4,792 plants/acre) in the 1991 experiment, and 62 percent of the plants were 2 to 4 feet tall. Twig utilization of the lotebush regrowth averaged 98 percent for the two grazing periods in 1991 (Table 3), and goats reduced lotebush heights to 3 inches or lower. Crude protein content of lotebush regrowth was 18 percent at the end of each grazing period in 1991, and IVDMD was 59 and 56 percent for the first and second grazing periods, respectively. The goats browsed the lower canopies of mature lotebush plants after regrowth of plants in the experimental plots had been utilized. Lotebush browse yields were estimated at 37 and 23 g/plant (1.3 and 0.8 oz/plant) during grazing periods 1 and 2, respectively (Table 3). Total yields of lotebush regrowth were calculated to be about 500 lb/acre.

These data suggest that lotebush regrowth is of high nutritional quality and palatable to Angora goats. Angora goats may be effectively used as a biological management tool to suppress lotebush regrowth by grazing for short intervals with a high stocking density of goats.

Table 3. Utilization, heights, yields, crude protein (CP), and in vitro dry matter digestibility (IVDMD) of lotebush regrowth at the end of two grazing periods following top removal on April 12, 1991, at Carlsbad, Texas. Values are the mean of four replications.

	Utilization		Caged plants			
Grazing period	twigs browsed	canopy height	canopy height	yield	CP	IVDMD
	%	—inches—		g/plant	—%—	
1	98	2	12	37	18	59
2	99	3	7	23	18	56

The relatively low yields of lotebush browse do not appear to justify the cost of a mechanical treatment to remove the old growth of mature shrubs. However, other factors to be considered would be decreased labor requirement for gathering animals and the potential for increased yield of herbaceous forage resulting from decreased lotebush competition. Herbaceous forage yields were not estimated in this study.

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Fourwing Saltbush Pastures as Winter Supplemental Forage for Yearling Angora Does

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Summary

Three 57-day winter grazing trials were conducted during December 1989 through January 1992 to determine the value of fourwing saltbush (*Atriplex canescens*) as a source of supplemental forage for yearling Angora does. Yearling does grazing fourwing saltbush-grass mixture pastures gained 0.1 lb/head during a dry winter and averaged gaining 2.4 lb/head during two wet winters. Yearling does grazing WW-Spar bluestem (*Bothriochloa ischaemum* var. *ischaemum*) pastures lost 2.2 lb/head during a dry winter and averaged losing 4.0 lb/head during two wet winters. Fourwing saltbush was readily browsed by the goats in all trials and contributed 86.2 percent of the diets of goats grazing saltbush-native grass mixture pastures during late January of Trial 3. Goat performance on saltbush-grass pastures was less than expected based on laboratory-determined crude protein and in vitro digestible dry matter values for fourwing saltbush. Fourwing saltbush leaves averaged 11.5 percent crude protein and 73.4 percent digestible dry matter during the dry winter. Saltbush stem tips (leaves plus distal 3 inches of twigs) averaged 11.8 percent crude protein and 57.5 percent digestibility during the two wet winters. Dormant WW-Spar bluestem leaves averaged 4.0 percent crude protein and 47.1 percent digestibility for the three trials.

Introduction

Concentrated supplemental feeds are generally provided to livestock during winter because the nutrient content of rangeland forages is less than that required for acceptable livestock performance. Fourwing saltbush (*Atriplex canescens*), a native, evergreen drought-tolerant shrub, has long been recognized as a valuable source of supplemental nutrients for livestock and wildlife, especially during periods when grasses and forbs are dormant and low in nutritional value. High laboratory-determined crude protein and in vitro digestibility values of the winter leaves of fourwing saltbush indicate the shrub might be a valuable nutrient source for Angora goats during winter (6,9).

Results from an in vivo digestibility trial in New Mexico showed that Angora goats fed a mixture containing 30 percent dried saltbush leaves retained a significantly higher percentage of the consumed nitrogen than those fed a mixture containing 30 percent alfalfa hay (4). Conversely, total feed intake and nitrogen retention were lower in Angora goats fed fresh fourwing saltbush leaves and stems ad libitum compared with saltbush plus a concentrate containing 32 percent crude protein in a similar trial in Texas (7). Results from a grazing trial during September-October 1985 suggested that fourwing saltbush was relatively unpalatable to Angora weanling kids and that weanling kids did not receive adequate nutrition from saltbush during this period to maintain their weight (7).

Three grazing trials were conducted during the winters of 1989 through 1992 to determine the feeding value of western Texas accessions of fourwing saltbush for yearling Angora goats.

Experimental Procedures

Three winter grazing trials were conducted at the Texas A&M University Agricultural Research and Extension Center near San Angelo to evaluate yearling Angora doe performance on fourwing saltbush. Grazing treatments evaluated for each trial included: 1) a mixture of fourwing saltbush and various native grasses, including sand dropseed (*Sporobolus cryptandrus*), slim tridens (*Tridens muticus*), silver bluestem (*Bothriochloa saccharroides*), tobosagrass (*Hilaria mutica*), and Texas wintergrass (*Stipa leucotricha*); or 2) WW-Spar old world bluestem (*Bothriochloa ischaemum* var. *ischaemum*).

Water, salt, and a mineral supplement containing 12 percent phosphorus and 12 percent calcium were provided ad libitum in all trials. The goats were treated with levamisole for internal parasite control before initiation of each trial. Temporary, plastic shelters were provided in the bluestem pastures for protection during cold and/or rainy weather. Animals were fasted 15 hours before initial and final weights were taken. Data were subjected to analyses of variance. Significant year by treatment interactions precluded pooling data of the three trials.

Grazing Trial 1 (1989-90). Sixty yearling Angora does (average weight 41 lb) were used in a grazing trial during December 6, 1989, to February 1, 1990. The does were randomly divided into groups of 5 or 10 head each and assigned to the two grazing treatments. There were four replications of each treatment. Ten goats were placed in each of four 5-acre pastures containing the saltbush-grass mixture. Five goats were placed in each of four 2.5-acre bluestem pastures. Growing conditions were very poor, and there was no green herbaceous forage in either treatment. Supplemental feed (20 percent crude protein grain cubes at 0.5 lb/head/day and alfalfa hay at 1.0 lb/head/day) was provided in both treatments during extremely cold or cold-wet weather. Weather conditions were mild during most of the trial. Forage samples were collected on February 1, 1990, for laboratory analyses. Several grass samples were randomly clipped to a 1-inch stubble height in each pasture. The distal 3 to 6 inches of randomly selected fourwing saltbush branches from several plants were clipped and dried at 100°F. Leaves of the grasses and fourwing saltbush were removed from the stems, then ground to pass a 20-mesh screen in a Wiley mill for laboratory analyses. Samples were analyzed for percentage of crude protein by the standard Kjeldahl procedure (2), and digestible dry matter was estimated in vitro by a two-stage process (8).

Trial 2 (1990-91). Seventy-eight Angora yearling does (average weight 40 lb) were used in a grazing trial during December 5, 1990, to January 31, 1991. The does were randomly divided into groups of 9 or 10 head each and assigned to four replications of each of the two grazing treatments previously mentioned. About 11.8 inches of rain were received, and growing conditions were excellent for the 3 mo before initiation of the study. Supplemental feed as 20 percent crude protein grain cubes were fed at 0.5 lb/head/day during extremely cold or cold-wet weather. Forage samples were collected at initiation and termination of the trial for laboratory analyses. Grass leaves were collected from randomly selected plants in each pasture. The distal 2 to 3 inches of several branches were clipped from randomly selected fourwing saltbush plants in each pasture. All samples were dried at 100°F and ground to pass a 20-mesh screen in a Wiley mill for laboratory analyses as described above.

Trial 3 (1991-92). Eighty Angora yearling does (average weight 40.5 lb) were used in a grazing trial during December 4, 1991, to January 30, 1992. The WW-Spar bluestem fields were shredded in August 1991. About 10 inches of rainfall were received, and growing conditions were excellent for the 3 mo before initiation of the study. Forbs, such as redseed plantain (*Plantago rhodosperma*), upright prairie coneflower (*Ratibida columnifera*), dakota verbena (*Verbena bipinnatifida*), and virginia pepperweed (*Lepidium virginicum*) were abundant, but very small, in the fourwing saltbush-grass mixture pastures. Forbs were rare or absent in the bluestem pastures. Cottonseed at 1.0 lb/head/day and grass hay at 1 lb/head/day were fed during extremely cold or cold-wet weather. Forage samples were collected at initiation and termination of the trial for laboratory analyses. Fecal samples were collected from four to five goats from each fourwing saltbush-grass mixture pasture on January 29, 1992. Diets of the goats were estimated by microhistological analysis of the fecal samples (1,3).

Results and Discussion

Yearling Angora does readily consumed fourwing saltbush in the fourwing saltbush-grass mixture pastures during all trials, even during wet winters when annual forbs were abundant. The mean weight gain was significantly greater for the fourwing saltbush-grass mixture pastures compared with the WW-Spar bluestem pastures in all experiments (Table 1). Growing conditions were very poor before and during Trial 1 (1989-90). Forbs were rare or absent in all pastures. Yearling Angora goats grazing saltbush-native grass pastures gained 0.1 lb/head during the 57-day trial, whereas those grazing dormant bluestem pastures lost 2.2 lb/head. Fourwing saltbush leaf crude protein and in vitro digestibility averaged 11.5 and 73.4 percent, respectively, and the dormant native grasses contained 4.9 percent crude protein and 47.1 percent digestible dry matter (Table 2). Dormant WW-Spar bluestem contained 4.0 percent crude protein and 53.3 percent digestible dry matter.

Growing conditions were considered excellent for Trials 2 (1990-91) and 3 (1991-92) because at least 10 inches of rain were received during the 3-mo period before initiation of each of these trials. Annual forbs were abundant in the fourwing saltbush-grass pastures, but the forbs were small and did not appear to be used by the goats during the trials. Forbs were rare or absent in the bluestem pastures. Goats grazing the saltbush-native grass pastures gained 3.4 and 1.3 lb/head during Trials 2 and 3, respectively, whereas goats grazing dormant bluestem pastures lost 4.6 and 3.4 lb/head during the same trials, respectively (Table 1). Diets of the Angora goats grazing saltbush-native grass mixture pastures during late January in Trial 3 included 86.2 percent fourwing saltbush (S.E. 3.1 percent; range 53.3 to 98.3 percent), 8.7 percent grasses (S.E. 1.4 percent; range 0 to 19.2 percent), and 5.1 percent forbs (S.E. 2.5 percent; range 0 to 39.8 percent).

Crude protein and in vitro digestible dry matter remained relatively constant for all forage components during Trials 2 and 3. Fourwing saltbush stem tip crude protein and digestibility averaged 11.6 and 60.0 percent, respectively, during Trial 2 (Table 2). Crude protein values were similar for Trial 3, but digestibility was about 5 percent lower than in Trial 2. Dormant native grass leaves averaged 6.2 and 7.2 percent crude protein for Trials 2 and 3, respectively, which was 2 to 3 percent greater than bluestem crude protein (Table 2). However, the bluestem leaves averaged about 8 percent greater digestible dry matter than the native grasses. Shredding the WW-Spar bluestem pastures in August 1991 did not appear to enhance its growth or nutritional value. Late-season growth was less than expected, possibly because of cool temperatures and cloudy skies during late summer and earlier-than-normal freezing temperatures.

Table 1. Mean weight changes (lb) of yearling Angora does grazing fourwing saltbush-native grass mixture pastures or WW-Spar bluestem pastures during 57-day winter (December-January) trials in 1989-90, 1990-91, and 1991-92.

Grazing treatments	Trials 1989-90	1990-91	1991-92
Fourwing saltbush - grass mixture	0.1	3.4	1.3
	*	*	*
WW-Spar bluestem	-2.2	-4.6	-3.4

*Indicates significant ($P \leq 0.05$) differences by the F-test statistic.

Table 2. Laboratory-determined crude protein (CP) and in vitro digestible dry matter (IVDDMD) of a fourwing saltbush-grass mixture and WW-Spar bluestem pasture components during first week of February for Trial 1 (1989-90) and during first week of December and first week of February for Trials 2 (1990-91) and 3 (1991-92).

Pasture/components	1st wk December CP	1st wk December IVDDMD	2nd wk February CP	2nd wk February IVDDMD
		%		
Trial 1 (1989-90)				
Fourwing saltbush - grass mixture				
fourwing saltbush (leaves)	—	—	11.5	73.4
dormant grass leaves	—	—	4.9	47.1
WW-Spar bluestem				
dormant grass leaves	—	—	4.0	53.3
Trial 2 (1990-91)				
Fourwing saltbush - grass mixture				
fourwing saltbush (stem tip)	11.5	60.9	11.7	59.0
dormant grass leaves	6.6	36.2	5.8	38.4
WW-Spar bluestem				
dormant grass leaves	4.2	45.6	3.6	44.5
Trial 3 (1991-92)				
Fourwing saltbush - grass mixture				
fourwing saltbush (stem tips)	11.7	55.9	12.1	54.3
dormant grass leaves	7.1	35.6	7.4	33.2
forbs	—	—	18.3	69.5
WW-Spar bluestem				
dormant grass leaves	4.1	42.7	3.8	43.0

Laboratory-determined concentrations of crude protein and digestible dry matter in fourwing saltbush leaves and stem tips exceeded minimum maintenance requirements for goats (5). This suggests that fourwing saltbush should have provided a diet sufficient for growth of young goats. However, the performance of yearling goats grazing saltbush-native grass pastures was less than expected according to laboratory analyses, particularly during the dry winter. We speculate that there may be secondary metabolites in western Texas fourwing saltbush forage that interfere with nutrient utilization or intake. Furthermore, the protein nitrogen in the forage may be rapidly hydrolyzed in the rumen, absorbed as ammonia, and excreted in the urine. However, results from these grazing trials indicate that fourwing saltbush pastures can be valuable as a source of supplemental nutrients during winter for yearling Angora goats.

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PR-4940

Supplemental Feeding of Angora Female Kids on Rangeland

J.E. Huston, C.A. Taylor, C.J. Lupton, and T.D. Brooks

Summary

Angora female kids were grazed on Edwards Plateau rangeland to determine effects of supplemental feeding and level and source of supplemental protein on weight gain and mohair growth. The study was conducted during two consecutive fall seasons at the Texas A&M University Agricultural Research Station at Sonora. Treatments included a negative control (NC) and three supplements (corn, C; corn-cottonseed meal, C/CSM; and corn-cottonseed meal-fish meal, C/CSM/FM) fed at levels to provide 0.8 Mcal digestible energy (DE) and either 0.04 (C) or 0.16 (C/CSM and C/CSM/FM) lb of crude protein (CP) per goat per day. Fish meal provided 35 percent of the CP in the C/CSM/FM supplement. The kids were grazed together on typical Edwards Plateau rangeland and separated into treatment groups for feeding three times per week. The study included 98 and 88 goats in year one and year two, respectively. Supplement consumption and forage intake were estimated for 10 kids per treatment group using dual marker procedures.

Greater weight gains were observed for fed groups versus NC (P<0.05) and for high-protein (C/CSM and C/CSM/FM) versus C groups (P<0.05). Fleece weights were greater for fed groups versus NC (P<0.01). Weight gain between the high-protein groups (C/CSM versus C/CSM/FM) were not different (P>0.05). Fleece weights and fiber diameters were greater in kids fed C/CSM/FM than in those fed C. In each case, those fed C/CSM were intermediate.

Conclusions are that supplemental nutrients will increase weight gain and mohair growth in kid goats grazing rangeland of declining quality in the fall. High-

protein supplements appeared more effective, especially for increasing weight gain.

Introduction

Angora goats breed seasonally during the fall (September to November) and give birth in late winter, just before favorable spring conditions. The March-April-May period usually provides good nutrition and temperature conditions for lactation by the dam and growth by the young kid. By weaning at about 5 mo of age, the kids are more dependent on forage than on mother's milk for the required nutrients. The period between weaning and first breeding (approximately 14 mo) is critical for Angora females. During at least 12 mo of this 14-mo period, the typical Edwards Plateau rangeland does not provide an adequate level of nutrition. Comparing requirements (5) with nutrient content of forages (3) suggests that both energy and protein levels are insufficient for proper development of these young goats.

We conducted this study to determine the effects of supplemental feeding and of feed protein level and source on growth rate and fleece characteristics of weaned Angora female kids on Edwards Plateau rangeland.

Materials and Methods

Angora female kid goats (approximately 6 mo of age and weighing 40 lb) were assigned after weaning during two consecutive fall seasons to receive one of four feeding treatments while grazing/browsing on rangeland. Ninety-eight and 88 animals were fed for 92 and 84 days in 1989 (Trial 1) and 1990 (Trial 2), respectively. In each trial, the kids were kept in a common herd. Three times per week the kids were gathered, separated into treatment groups, and fed as indicated in Table 1. The negative control group (NC) was not fed. The three fed groups received either corn (C) or a mixture containing primarily corn and cottonseed meal (C/CSM) or corn, cottonseed meal, and fish meal (C/CSM/FM).

The supplements were formulated so that if consumed at the target feeding level, the fed groups would consume 0.8 Mcal digestible energy (DE) and either 0.04 (C) or 0.16 (C/CSM and C/CSM/FM) lb of crude protein per kid per day. Of the 0.16 lb of crude protein in the C/CSM and C/CSM/FM supplements, the ruminally undegraded portions were estimated as being 40 and 55 percent, respectively.

Forage diet determinations. Diet samples were collected weekly from a minimum of four esophageally fistulated goats during the last 60 days of each trial. These diets were described according to plant species and in vitro digestibility (6). The plant species selected by the goats were grouped into grasses, forbs, and browse. Averages were computed across collection periods for presentation in this report (Table 2). The estimates of digestible dry matter (DDM) also were averaged over collection periods.

Table 1. Composition of supplemental feeds in a study with Angora female kids on rangeland.

	Treatment			
Item	Control	Corn	C/CSM	C/CSM/FM
Ingredients, %				
Corn		100	37	45
Cottonseed meal			60	35
Fish meal				17
Molasses			3	3
Total	0	100	100	100
In vitro DDM,%				
Supplements				
1989		80.1	71.5	71.8
1990		81.9	76.8	77.5

Table 2. Composition of diets of female Angora kid goats grazing Edwards Plateau rangeland during two consecutive fall seasons.

	Class of forage in diet, %			
Item	Grasses	Forbs	Browse	Diet DDM[a], %
Year 1 (1989)	4.6	0.4	94.8	42.7
Year 2 (1990)	5.5	49.0	45.5	55.0

[a]Digestible dry matter.

Intake determinations. Intakes of forage and supplement were determined by a dual-marker procedure in 10 kids from each treatment group during the last 30 days of each trial. Total fecal output was estimated using a continuous release chromic oxide bolus technique (2). The boluses were administered 7 days before collection of feces on individual kids on 3 consecutive days. During the 7-day adjustment period, supplements fed were marked with ytterbium nitrate by spraying a solution on the dry feed and mixing. Fecal samples were analyzed for chromium and ytterbium by atomic absorption. Samples were prepared for analyses by grinding, ashing, perchloric acid oxidation of the ash, and bringing to standard volume in acid solution. Fecal output (thus intake) of the supplement was estimated by the ytterbium concentration in the feces of the individual goats. We assumed that the average consumption of the supplemental feed by the 10 dosed kids was equal to the average consumption of the entire group. Consumption by the individuals was then estimated by the relative concentration of ytterbium in the feces. Total fecal output (TFO) was estimated by dividing the concentration of chromium in the feces into the chromium release rate of the bolus.

$$\text{TFO, g/d} = \frac{\text{Chromium release rate of bolus, mg/d}}{\text{Chromium concentration in feces, mg/g}}$$

Fecal output from forage (FFO) origin was estimated by subtracting the feces of concentrate origin from total feces. Forage intake (FI) was then estimated by dividing the FFO by the indigestibility of the forage, estimated by in vitro digestion of diet samples.

$$FI, lb/d = \frac{FFO, g/d \div 454}{(1 - (DDM \div 100))}$$

Fleece measurements. The goats were sheared before the start of the feeding periods and on the day that the final weights were taken. The fleeces removed at the termination of each trial were identified and transported to the Wool and Mohair Research Laboratory, San Angelo, Texas, for characterizing. Data obtained on each fleece included grease weight, yield, staple length, and presence of med and kemp by standard ASTM methods (1) and fiber diameter using the Peyer Texlab FDA 200 System (4).

Results and Discussion

Supplemental feeding resulted in increased total nutrient intakes (Table 3) and increased weight gain and fiber production (Table 4) with little or no adverse effects on fiber characteristics. The higher protein feeds were generally more effective than corn, but the fishmeal-containing supplement did not give additional benefits.

Table 3. Effects of supplemental feeding on forage and digestible dry matter (DDM) intake in Angora female kids on rangeland (1989-1990).

	Treatment			
Item	Control	Corn	C/CSM	C/CSM/FM
Number of goats	20	16	19	17
Target feeding rate, lb/d	0	.45	.51	.50
Intake, lb/d				
Supplement	0^{a}	.42^{b}	.42^{b}	.35^{b}
Forage	1.64^{a}	1.46^{a}	1.55^{a}	1.64^{a}
Total DM	1.64^{a}	1.88^{b}	1.97^{b}	1.99^{b}
DDM	.80^{a}	1.06^{b}	1.07^{b}	1.10^{b}

^{ab}Means in the same row not sharing a common superscript differ ($P<0.05$).

Table 4. Effects of supplemental feeding on live weight gain (LWG), mohair production, and fleece characteristics in Angora female kids on rangeland (1989-1990).

	Treatment			
Item	Control	Corn	C/CSM	C/CSM/FM
Number of goats	35	50	48	50
LWG, lb	.5^{a}	3.2^{b}	8.0^{c}	7.8^{c}
Clean fleece, lb/100 lb	4.5^{a}	5.1^{b}	5.3^{bc}	5.6^{c}
Fiber diameter, µm	26.2^{a}	25.8^{a}	26.8^{ab}	27.5^{b}
Staple length, in.	3.03^{a}	3.02^{a}	3.24^{b}	3.13^{ab}
Med fibers, %	.30^{a}	.35^{ab}	.47^{b}	.37^{ab}
Kemp fibers, %	.61^{a}	.54^{a}	.65^{a}	.71^{a}

^{abc}Means in the same row not sharing a common superscript differ ($P<0.05$).

Diet differed somewhat between the 2 years (Table 2), which is a common occurrence for the Edwards Plateau region. The goats depended heavily on liveoak and juniper (browse) during 1989 but had access to plentiful forbs during 1990. Response data were pooled for the two trials. Supplement consumption levels were not according to those prescribed, especially for C/CSM/FM, which may have slightly affected the results. The lowered consumption of the C/CSM/FM supplement probably was a result of low palatability. Forage intake was not affected by supplements ($P>0.25$), but the low forage consumption by the C group compared with the high-protein groups ($P = 0.14$) suggests that supplement type may influence forage intake. However, the most important finding was that the supplements were mostly additive rather than substitutive under the conditions of this study. This resulted in greater dry matter and digestible dry matter intake by supplemented goats, regardless of the type of supplement.

Supplemental feeding increased weight gain of the kids, and the higher protein feeds were more effective compared with corn (Table 4). Because total intake of DDM was comparable among the supplemented groups (Table 3), the increased gain can be attributed to increased protein intake, not increased dry matter. The failure of the C/CSM/FM to produce an additional increase is a likely result of lowered total protein intake because of reduced supplement consumption (Table 3).

Fleece production was increased by feeding, especially by the higher protein supplements (Table 4). The kids fed the C/CSM/FM supplement produced more (0.5 lb/100 lb) fleece consisting of coarser (1.7 µm) fibers compared with those fed corn. Those fed the C/CSM were intermediate to C and C/CSM/FM in fleece production and fiber fineness. For staple length, those fed the C/CSM supplement produced longer mohair than those fed C, and the C/CSM/FM group was intermediate. No effects were apparent for med or kemp.

These results show that supplemental feeding will increase the total intake and performance of weaned Angora female kids grazing/browsing Edwards Plateau rangeland during the fall season. Protein is important as a nutrient for this class and age of goat beyond its possible effect of stimulating forage intake. An additional benefit from supplements with ruminally undegraded protein in the form of fish meal was not demonstrated in this study. However, there were some indications of effects of increased undegraded protein even at lower total protein intake. The small differences that were observed, although not statistically significant, included increased forage intake, increased clean fleece, and increased fiber diameter. It is suggested that, had supplement intake occurred at target level, an effect of an elevated escape protein would have been observed.

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Weight Changes and Productivity of Cattle, Sheep, and Angora Goats at Three Stocking Rates

J.E. Huston, P.V. Thompson, and K.W. Bales

Summary

A 4-year study was conducted at the H.D. Winters Ranch, McCulloch County, Texas, to determine the effects of stocking rate on cattle, sheep, and Angora goats grazing together. As stocking rate increased from 20 ac/animal unit (au) to 10 ac/au, cow weight losses during winter increased from about 10 percent to more than 16 percent of fall weight. Spring and summer gains were corresponding but in reverse. Weight changes in sheep were in reverse of those in cattle; that is, sheep at the higher stocking rate lost less in winter and gained less during spring/summer. Stocking rate did not affect weight changes in goats. Increased stocking rate resulted in higher fleece production in sheep and lower production in goats, especially in the spring mohair clip. No differences in weights of offspring were found. Conception rate data did not clearly reflect treatment effects, and some explanatory discussion is included in the text.

Introduction

Combination grazing with two or three livestock species is a common practice in the Edwards Plateau region of Texas. Diets of cattle, sheep, and goats differ in the proportion of the different plants and plant parts. Grazing a mixture of animal species encourages more uniform utilization (3).

Stocking rate affects both the productivity of the individual animal and that of the rangeland being grazed. As stocking rate is increased, the productivity of the individual animal decreases (e.g., lower weaning weights and wool production [6]). However, because of a greater number of animals at the higher stocking rate, productivity from the area is often greater. At extra-heavy stocking, productivity from both the individual animal and the area will decrease (5). We conducted a 4-year study at the H.D. Winters Ranch in McCulloch County to determine the relative effects of stocking rate on cattle, sheep, and goats grazed in common.

Experimental Procedure

Three pastures that had been described as similar in terrain and vegetation (3) were selected for determining the effects of stocking rate on reproducing herds and flocks of cattle, sheep, and goats. The pastures selected for high, medium, and low stocking rates contained 153, 753, and 407 ac and were stocked at 10, 15, and 20 ac/au, respectively. A constant proportion of 50 percent cattle, 25 percent sheep (5 sheep/au), and 25 percent Angora goats (7 goats/au) was grazed in each of the three pastures.

Before the initiation of this study, the pastures had been stocked at an equal rate of 15 ac/au but with different proportions of livestock species. Therefore, data were not collected during year 1 because response could be strongly influenced by previous range use. The data presented were collected during years 2, 3, and 4 of the 4-year study.

The animals used in this study included Hereford X Brangus cows bred to Beefmaster bulls and Rambouillet ewes and Angora does respectively bred to Rambouillet rams and Angora billies. At the beginning of the study, the herds and flocks consisted of animals of mixed ages that had been inspected and determined to be sound for reproduction. During the fall of each year, all animals were inspected, and those removed were replaced with young animals of similar breeding from ancillary groups of animals on the ranch. Because of superimposed supplemental feeding treatments for the beef cows, the cows were rerandomized each fall among the stocking rates. On the other hand, sheep and goats that were not culled remained on the respective stocking rate treatments until the end of the study. Although feeding differed within groups for cows, feeding treatments across stocking rates were the same. Management practices, including feeding, were the same for sheep and goats across all stocking rates.

It was necessary, because of attrition from various causes, to delete data from some animals. For each year, the following criteria were used to determine what data were included in the analyses:

Cattle - Cows that were either palpated pregnant in the fall or were added pregnant as replacements and that gave birth to and weaned calves.

Sheep - Ewes that were present during the fall, matched to live lamb(s) in the spring, and evaluated the subsequent spring for either having given birth or having been barren.

Goats - Same as for sheep.

Data collected included weight changes of adults, weaning weights of offspring (adjusted to weight of weaned offspring per adult), fleece weights (grease), and pregnancy rates. Differences in the response criteria among stocking rates were analyzed with the General Linear Model and Duncan's procedures (4). The effects of stocking rate on the response criteria were determined by regression analysis (4).

Results and Discussion

Weight changes were different for cattle and sheep in the different stocking rates (Table 1). Cows at the low stocking rate lost less weight during the fall and winter and regained less weight during the subsequent spring and summer than those at the high stocking rate ($P < 0.05$). The cows at the medium stocking rate were intermediate in weight changes during both periods. Weight changes for the ewes were in the reverse order compared with the cows. The greatest weight loss and weight gain for ewes occurred at the low stocking rate, and significantly lower losses and gain ($P < 0.05$) were at the high stocking rate. Weight changes for Angora does were atypical compared with cows and ewes and were not different at the different stocking rates. An important difference was that the spring weights for goats were recorded at shearing, which was before kidding. The fact that the goats were pregnant accounts for the absence of a full-winter weight loss and a spring-summer gain. However, the lack of a difference in weight change among the stocking rates is an unbiased indication that goats were unaffected or less affected than cattle or sheep.

Production data were highly variable, and weight of offspring did not differ among rates of stocking (Table 2). Differences in fleece production among stocking rates were in reverse order for sheep and goats. The most striking difference was in the spring mohair clip. In a concurrent study (1), it was determined that relative mohair production in spring and fall clips in the Edwards Plateau and Rio Grande Plains regions were reversed, presumably because of winter forage supplies. In the Edwards Plateau region, the local variety of live oak (*Quercus virginiana*) is a primary constituent of goat diets during winter but provides only marginal protein nutrition. The lower mohair weight of the spring clip

Table 1. Effects of stocking rate on weights of cattle, sheep, and Angora goats on rangeland.

Item	Stocking rate Low	Medium	High
Stocking rate			
Ac/au	20	15	10
Au/section	32	43	64
No. of animals			
Cows	25	70	23
Sheep	50	137	47
Goats	36	71	29
Avg. fall wt, lb			
Cows	1097	1120	1115
Sheep	133	133	128
Goats	70	73	71
Avg. wt changes, lb[a]			
Cows: Fall to spring	-110[b]	-168[c]	-188[c]
Spring to fall	58[b]	80[b]	153[c]
Sheep: Fall to spring	-27[b]	-25[b]	-20[c]
Spring to fall	38[b]	30[c]	19[d]
Goats: Fall to spring	3	0	2
Spring to fall	-4	-4	0

[a] Goat weights were taken at spring (Feb.) and fall (Aug.) shearings (pre-kidding and at weaning, respectively).

[bcd] Means in a row not bearing a common superscript differ ($P<0.05$).

Table 2. Effects of stocking rate on production of cattle, sheep, and Angora goats on rangeland.

Item	Stocking rate Low	Medium	High
Calf/lamb/kid wt, lb/yr			
Cows	519	499	494
Sheep	86	74	74
Goats	44	43	41
Fleece production, lb/yr			
Sheep	8.1[a]	8.6[b]	8.7[b]
Goats:			
Spring clip	4.6[a]	4.3[a]	3.7[b]
Fall clip	4.0	3.8	4.0
Total	8.6[a]	8.1[b]	7.7[c]
Pregnancy rate, %			
Cows	92	89	87
Sheep[d]	97	86	94
Goats	65	47	47

[abc] Means in a row not bearing a common superscript differ ($P <0.05$).

[d] Chi-square analysis indicated a difference in pregnancy rate in sheep ($P<0.05$).

suggests that high stocking may have intensified the dependence of goats on oak for winter forage. Sheep, on the other hand, concentrate on short, high-quality forages when available. Both the body weights and fleece weights indicate that heavy stocking may have encouraged a greater supply of these high-quality, low-quantity plants that are somewhat uniquely available to sheep. Other workers have reported higher quality forage under high stocking (2).

Pregnancy rates were not different between stocking rates for cows or goats, but a chi-square analysis indicated a difference for sheep ($P < 0.05$). The lack of a statistical difference in pregnancy rate for cows is misleading in these results and is explained by the fact that the cows were reramdomized each year. Those that bred late in the breeding season had equal opportunity to be assigned to a more favorable treatment the second year, thus penalizing that treatment. The reverse is true also. A cow bred early in a favorable treatment could be assigned during the next year to a less favorable treatment but have an extended opportunity to breed back.

A better indicator of probability of conception in the cow herds is the fall to spring weight change data (Table 1). Other workers have reported strong relationships between weight change before the breeding season and conception rate. Generally, weight change greater than 15 percent of fall weight is too high for satisfactory conception. In this study, fall-to-spring weight loss for the low, medium, and high stocking rates were 10, 15, and 17 percent, respectively. Reproduction in sheep was benefitted by low stocking for a different reason. Whereas the cows were bred in April to June following a nutritionally stressful period and during lactation, sheep were bred in September and October during the growing season and 3 to 4 mo after cessation of lactation. The higher weight loss during the fall-winter period by the ewes under low stocking was more than compensated for during the growing season. The ewes were back in good condition for breeding.

Table 3 contains regression data on the effects of stocking rate on the measurements taken. Most relationships are negative; that is, as stocking rate increased, most measured responses decreased. Among these were weights of offspring of all three livestock species. In each case, the probability approached significance in the linear model and reached significance in sheep in the quadratic model ($P = 0.039$). Other negative effects were fall-to-spring weight change in cows (quadratic; $P = 0.018$), spring-to-fall weight change in sheep ($P = 0.0001$), and spring mohair clip in goats ($P = 0.003$). Positive effects included spring-to-fall weight change in cows ($P = 0.073$), fall-to-spring weight change in sheep ($P = 0.003$), and fleece weight in sheep (quadratic; $P = 0.025$).

Perhaps the most important finding of this study is that increased stocking rate probably has a greater adverse effect on cattle than on sheep and goats. Whereas cattle production will decline under heavy stocking because of the increased nutritional stress during winter, sheep and goat productivity may in some respects improve because of temporary improvements in diet quality. This should be viewed as a serious hazard in management. Long-term overgrazing that is not recognized and corrected will lead to serious range destruction.

Table 3. Regression relationships between stocking rate (X) and weights and production (Y) in cattle, sheep, and Angora goats on rangeland.

Livestock species	Dependent variable	Regression coefficient(s)		r	P
Cattle	Wt change				
	Fall to spring	-1.23		-.158	.152
	(Quadratic)	-20.5	+.20	-.310	.018
	Spring to fall	+2.01		+.197	.073
	Calf wt	-1.17		-.170	.123
Sheep	Wt change				
	Fall to spring	+ .23		+.184	.003
	Spring to fall	- .56		-.336	.0001
	Fleece wt	+ .015		+.122	.064
	(Quadratic)	+ .171	-.002	+.176	.025
	Lamb wt	- .305		-.114	.079
	(Quadratic)	-3.35	+.031	-.167	.039
Goats	Wt change				
	Fall to spring	- .01		-.01	.919
	Spring to fall	+ .061		+.07	.491
	Fleece wt				
	Spring	- .027		-.298	.003
	Fall	+ .002		+.02	.851
	Total fleece	- .025		-.161	.116
	Kid wt	- .15		-.173	.089

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Application of Fiber Metrology to Wool Marketing in Texas

F.A. Pfeiffer, C.J. Lupton, and N.E. Blakeman

Summary

We conducted a study to quantify the effects of presale objective measurements on traditional Texas wool warehouse sales and particularly to quantify the economic impact of making these measurements available before wool sales. Accumulations of wool (173 lots) were sampled in six West Texas warehouses before the 1990 and 1991 wool-selling seasons. Subsamples were tested for yield, vegetable content, fiber diameter, and staple length. The objectively measured information was provided to buyers before bidding for half the wool lots (OBJ) but was withheld for the other comparable half (SUB), these lots being purchased in the normal manner following subjective appraisal.

In 1990, wool buyers paid more ($0.12/lb, $P<0.05$) for wools for which objective measurements were available. The same effect was observed in 1991, but the difference ($0.07/lb) was not significant ($P>0.05$). Selling date had a significant influence ($P<0.01$) on prices in 1991 but not in 1990. Fiber diameter was negatively and significantly ($P\leq0.05$) correlated with price, regardless of marketing category (OBJ and SUB). Yield was positively and significantly ($P<0.01$) correlated with price for the OBJ wool lots in both years of the study. This situation was also true for the SUB wools in 1991. However, the correlation between price and yield was not significant for SUB lots in 1990. Staple length was positively correlated with price in both marketing categories and both years of the study.

The major implication of this study is that prices paid for wool can be increased by providing buyers with objective data on individual lots before sale.

Introduction

More than 15 years of basic research, instrument development, and large-scale, multinational textile mill trials have resulted in the adoption of a wool-marketing system called, "Sale-by-Sample" in Australia. In this system, important wool characteristics (including yield, vegetable content, fiber diameter, length, and strength) are measured on each lot of skirted and classed wool and made available to potential buyers before sale by public auction. In contrast, much Texas wool is still sold on a greasy basis in sealed-bid sales after subjective evaluation by the buyer.

Advantages for a wool-marketing system based on objective fiber measurements compared with the traditional subjective system have been enumerated (1,2) and far exceed the cost of testing. Apart from direct savings in wool handling at the selling centers, broader indirect improvements and savings have been reported in wool preparation, sheep breeding, wool packaging, and the overall efficiency of wool marketing. These have extended the benefits of the marketing system to producers, wool buyers, and processors. Such claims seem reasonable, considering the advantages accrued as a result of almost the whole Australian wool industry simultaneously adopting this form of marketing.

The question arises, "Would financial advantages accrue to a relatively small proportion of U.S. wool producers who sold objectively measured clips?" We designed an experiment to answer this question in the context of Texas fine wool produced in 1990 and 1991.

We had originally envisaged conducting this study using skirted and classed wools. However, because most of the prepared wools are sold with objective fiber information, warehousemen were reluctant to accommodate our experimental design, which called for half the wool lots to be sold without measurements. Consequently, the study was conducted using unprepared (original bag) wool, recognizing that sampling procedures might produce less representative samples than would be expected with classed wool lines.

Experimental Procedure

Twenty-five Texas warehouses were initially contacted to cooperate in this 2-year project. Five warehousemen consented to participate in 1990 and six in 1991. In each year of the experiment, multiple (74 in 1990, 99 in 1991) lots of wool were sampled under the supervision of Experiment Station staff. Core samples were tested for yield (CWFP), vegetable matter present (VMP), average diameter, and distribution by Yocom-McColl Testing Laboratories, Inc. Grab samples were tested for staple length and distribution at the TAES Wool and Mohair Research Laboratory, San Angelo, Texas. One half of all the lots tested was sold in the traditional manner on a subjective basis. In contrast, certificates summarizing the objectively measured information were available for all the lots representing the other half. Representative bags of all lots were also available for buyer inspection before sale. An attempt was made to place lots in the "subjective" (SUB) or "objective" (OBJ) categories in a random manner. However, in some cases, requests from individual producers to place their wool in one or the other category were honored. Other data collected in the study included date of sale, lot size (lb), and price received ($/greasy lb).

Mean values and standard deviations were calculated by sale category and year for each variable measured. Analysis of variance and Duncan's New Multiple-Range Test (3) were used to identify significant within-year differences between all mean values in the objective versus subjective sale categories. Finally, simple linear regression analysis was used to calculate correlation coefficients between prices received and objectively measured properties.

Results and Discussion

Table 1 shows the mean values and variability (standard deviations, SD) of the characteristics measured in the 1990 study summarized by marketing category. Although differences exist between objectively and subjectively sold lots in every characteristic, most of these were not significant (P>0.05). Thus, as planned, average selling dates, lot sizes, CWFP, VMP, fiber diameter, and staple length between the two marketing categories were not different (P>0.05). In contrast, the $1.57/lb paid for the OBJ lots was greater (P<0.05) than the mean value of $1.45/lb paid for the SUB lots. Thus, in 1990, wool buyers paid $0.12/lb more for the Texas original bag wools for which objective measurements were available compared with wool that they had only subjectively appraised. If the average cost of core testing (CWFP, VMP, and fineness) was $100, it follows that objective marketing would have paid in 1990 for lot sizes greater than 833 lb ($100 + $0.12/lb).

Table 2 summarizes similar data for the 1991 marketing year. From a statistical point of view, the nine mean values reported for the OBJ wool lots are not different (P>0.05) from the values reported for the SUB lots. Again, a higher mean price ($0.07/lb) was paid for the OBJ wool compared with the SUB wool, but in 1991 this difference was not significant at the 95 percent probability level. This is primarily due to the relatively high variability observed in wool prices in the 1991 season compared with the 1990 season. Specifically, a major price increase occurred on April 30, 1991, which added a great deal of variability to our price data (in both marketing categories). Despite this lack of significance, prices paid for OBJ lots were higher than for SUB wool. This gives us another positive indication that providing wool characteristics before sale can result in higher prices being paid.

Table 3 contains correlation coefficients (r values) for price versus measured characteristic by marketing category (OBJ and SUB) and year. The probability of the correlation being significant appears in parenthesis after the correlation coefficient. Thus, in 1990, selling date was not significantly correlated with price received (P>0.05). However, under 1991 marketing conditions, the correlations between price and selling date were both highly significant (P = 0.0001), this being a result of the April 30 price change that was alluded to previously.

For both years and marketing categories, price and lot size were inversely but not significantly related. This is contrary to popular belief that has maintained that

Table 1. Mean values and variability of characteristics measured in 1990 wool-marketing study.

Sale category	Objective		Subjective	
Number of lots	37		32	
	Mean	SD	Mean	SD
Selling date (day of year)	144.8	16.7	139.1	20.2
Weight (lb)	5781	5371	3594	2220
CWFP (%)	50.3	2.4	50.1	3.2
VMP (%)	1.1	.6	1.0	.4
Fiber diameter (µm)	19.6	.9	20.2	.8
SD of fiber diameter (µm)	3.6	.9	3.8	.3
Staple length (in.)	3.38	.38	3.33	.55
SD of staple length (in.)	.54	.24	.52	.16
Price ($/lb, greasy)	1.57[a]	.19	1.45[b]	.21

[a,b]Values in the same row with different superscripts differ (P<0.05).

Table 2. Mean values and variability of characteristics measured in 1991 wool-marketing study.

Sale category	Objective		Subjective	
Number of lots	47		52	
	Mean	SD	Mean	SD
Selling date (day of year)	124.5	20.5	127.6	19.7
Weight (lb)	7029	5257	6717	5292
CWFP (%)	53.1	3.9	52.3	4.5
VMP (%)	1.7	1.0	1.4	.8
Fiber diameter (µm)	20.3	.7	20.6	.7
SD of fiber diameter (µm)	3.7	.3	3.8	.3
Staple length (in.)	2.84	.62	2.76	.63
SD of staple length (in.)	.45	.15	.42	.14
Price ($/lb, greasy)	1.09	.29	1.02	.32

Table 3. Correlation coefficients for price versus objectively measured characteristic (P values in parenthesis).

Year	1990		1991	
Sale category	Objective	Subjective	Objective	Subjective
Number of lots	37	32	47	52
Selling date	.17 (.3119)	-.03 (.8481)	.53 (.0001)	.63 (.0001)
Weight	-.18 (.2830)	-.30 (.0975)	-.16 (.2843)	-.17 (.2208)
CWFP	.54 (.0005)	.12 (.5175)	.41 (.0039)	.44 (.0010)
VMP	-.15 (.3819)	-.07 (.7039)	-.25 (.0882)	-.47 (.0004)
Fiber diameter	-.32 (.0529)	-.40 (.0222)	-.32 (.0307)	-.35 (.0114)
Staple length	.30 (.0911)	.56 (.0009)	.61 (.0001)	.56 (.0001)

price declines as lot size decreases. CWFP and price were positively and significantly correlated for both years when the wool was sold with objective measurements. For unexplained reasons, this relationship did not hold for the 1990 subjectively appraised wools, an indication that price equity is more difficult to achieve when measurements are not used. VMP and price were negatively correlated. However, the only highly significant correlation of magnitude (-0.47) was found in 1991 for the subjectively appraised wools. These data suggest that vegetable contamination had little effect on price in 1990 but that in 1991 buyers responded to perceived (but not measured) vegetable content.

Fiber diameter and price were significantly and negatively correlated. The similarity of the correlation coefficients between OBJ and SUB categories suggests that the wool buyers are doing an adequate job of visually assessing average fiber diameter. Staple lengths were uniformly longer in 1990 than in 1991 (Tables 1 and 2). This was a direct result of several 6-mo clips being included in the 1991 trial. For three out of four groups, price and staple length were highly correlated. For unexplained reasons, the correlation was not significant ($P>0.05$) for price versus staple length in the objective category in 1990.

Pre-sale availability of objective measurements on wool lots appears to have made a positive impact on prices paid for original bag wool in West Texas in 1990 and 1991. Assuming a fixed cost of $100 for yield and fineness testing, minimal lot sizes of 833 and 1,429 lb in 1990 and 1991, respectively, would have been required for this practice to be profitable. A clear implication of this study is that prices paid for wool can be increased by providing buyers with objectively measured wool data before the sale.

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Cashmere Production, Measurement, and Research Update

N.E. Blakeman, C.J. Lupton, M. Shelton, F.A. Pfeiffer, and T. Willingham

Summary

This report condenses current knowledge of cashmere production, harvesting, and fiber characterization. In addition, cashmere-related research that was conducted at the Texas Agricultural Experiment Station, San Angelo Unit, between 1988 and 1991 is described.

Introduction

Cashmere is considered to be a type of fiber rather than a specific breed of goat. Numerous breeds of goats produce cashmere, e.g., the Alashanzouqi, Erlangshan, Xinjiang, and Liaoning breeds of China; the Pashmina in India; the Boar goat in South Africa; and the feral goats in Australia and New Zealand. It has been estimated that 10 to 20 percent of Texas meat-type or Spanish goats produce some cashmere. Dairy goats produce very small quantities of cashmere.

A cashmere goat characteristically produces a double-hair coat consisting of coarse guard hair and fine down. Mean fiber diameter of cashmere generally ranges from 13 to 19 microns (μm), while the guard hair typically ranges from 50 to 100 μm. The down is mechanically separated from the guard hair and is used to make luxury garments. The guard hair has limited commercial value.

Traditional cashmere-producing areas of the world are China, Mongolia, Iran, and Afghanistan. Europe and the United States are the major users of cashmere. Producers in Australia and New Zealand have been selecting for cashmere production among the feral goat population and are producing an increasing amount of cashmere for the world market. These countries have also been exporting selected cashmere breeding stock and semen to the United States and other countries interested in producing cashmere. Cashmere production in the United States is a young but growing industry. Interest in cashmere production began in the early 1980's when the price of cashmere was nearing $100/lb. However, prices have fallen considerably from this value although they are still higher than most animal fibers (April 1992, approximately $25/lb).

Goats can be used for range (20) and forest (17) management to control brush and undesirable forbs or may be used as backyard weed eaters. Much of the current interest in cashmere is associated with the meat-goat industry in Texas. By selecting for goats with harvestable amounts of cashmere in animals currently used for meat production or as range management tools, producers can increase the return per animal without substantially changing management and production practices. The economics of cashmere/goat meat production have been reported by several authors (14, 21). Spanish goats typically produce from 0 to 0.25 lb of cashmere per year. Improved cashmere types and flocks that have benefitted from several generations of selection may produce as much as 0.5 lb cashmere per head per year.

Characteristics of Cashmere

Physical characteristics of cashmere are summarized in Table 1. Microscopically, cashmere down fibers have a similar appearance to merino wool of comparable dimensions. The fiber cross sections have a high degree of circularity. Fibers that have been combed (versus sheared) contain roots. Most fibers also contain a tip. In contrast, the guard hairs consist of three distinct parts: the epidermis, cortical layer, and medulla. The continuous medulla constitutes a large portion of the outer-coat fibers, and this feature combined with the relatively large size permit easy differentiation between guard hair and cashmere. The cross sections of guard hairs vary from nearly circular to elliptical or kemp-like.

In the raw state, cashmere contains 10 to 50 percent impurities. Grease and suint typically compose less than 5 percent of this amount, the bulk of the impurity being sand and dirt. Heavy contamination of cashmere fleeces with vegetable material is rare.

Cashmere from different sources varies in length from 0.5 to 3.5 inches. Generally, fibers longer than 1.4 inches (and finer than 16.5 μm) are used to make knitting yarns. Cashmere shorter than 1.4 inches is used predominantly by the weaving trade. Compared with other animal fibers, cashmere is relatively weak, having about 10 percent less strength than wool and 40 percent less than kid mohair. However, lack of strength does not appear to affect wearability because textiles composed of cashmere will typically outwear similar structures made of wool.

Harvesting and Clip Preparation

Harvesting of cashmere may be achieved either by shearing or combing. Combing is performed by hand with a brush or special comb to collect the fibers. This is a time-consuming and labor-intensive method although it may be suitable for limited numbers of goats or when labor is plentiful and inexpensive. Removal of cashmere by combing produces a product that is relatively free of guard hair compared with that obtained by shearing, although the combed fleece may still contain as much as 20 percent guard hair by weight. Combing must be done regularly over a period of several weeks because all the cashmere is not shed at once. It helps to have tame animals that can be restrained easily.

Shearing is conducted with the same equipment used for sheep or Angora goats. Since most cashmere goats have little or no down on their lower legs or bellies, animals may be shorn in a standing position using some type of head restraint. In Texas, however, most are shorn in a manner similar to that used for Angora goats with the feet tied. Spanish goats are difficult to shear Australian style and usually need some type of restraint during shearing.

The growth of cashmere is dependent on photoperiod. Down begins growing during late summer, when day length starts to decrease, and continues to grow until midwinter. When day length begins to increase, cashmere will begin to shed. Some goats retain their fleeces into the spring before shedding begins, and a few animals produce small amounts of cashmere year round.

It is important to time the shearing so that a maximum amount of down is obtained. Goats that are shorn too early in the season will shear less than their potential, but waiting too late to shear may result in some cashmere being lost to shedding. Since shearing is required during the cold part of the year (late December to early February), the animals might require shelter and/or extra feed for several weeks after shearing to prevent death losses from chilling.

Having a properly prepared clip can increase the value of the product. Fleeces should be packaged separately in the absence of specific knowledge on how to prepare cashmere bulk lots. Animals should be sorted by color before shearing, and white and light-colored animals should be shorn first to minimize contamination of the white cashmere with fibers from colored goats. Detailed instructions on clip preparation can be found in the *Guide to Clip Preparation* published by the American Cashmere Growers Marketing Co-op, P.O. Box 1105, Castle Rock, CO 80501.

Selection

Selection of cashmere goats should be practiced with the multiple objectives of minimizing mean fiber diameter of down (since higher prices are paid for finer fibers) while maximizing down and meat production (18). Fiber diameter and fleece weight are positively correlated, so that selection for finer fiber generally results in reduced fleece weights. This can be overcome only through increased length and density of fibers or more covering on larger sized animals. A down staple length of at least 1.25 inches should be maintained in the flock, as shorter staple lengths will not command optimum prices.

Selecting for color should not be overly emphasized. Sometimes, colored fiber is desirable. If a producer decides to breed only white animals, this can be selected for easily because white is dominant in cashmere goat breeding.

Visual appraisal should be used to evaluate animals for soundness and to assess down for cashmere character. Animals showing mohair or cashgora type hair characteristics should be culled. Objective measures of fleece characteristics aid the selection process.

Characterization of Cashmere

For characterization of cashmere fibers, objective measurements are used as much as possible because visual appraisal of animal fiber characteristics is relatively inaccurate. Style and character are the only traits in Table 1 that cannot be measured objectively. For a complete discussion of sampling and measuring procedures for all the characteristics of interest to a commercial cashmere processor, the reader is referred elsewhere (15). In this report, we will simply summarize those sampling and measuring procedures of interest to the cashmere producer.

Sampling Procedures

For individual goats, the sample submitted for testing is normally taken from the mid-side (see Figure 1).

Table 1. Ranges for important cashmere goat and cashmere characteristics.

Body weight (lb)	60 - 150
Fleece weight (hair-in; unscoured, lb)	.15 - 2.25
Average fiber diameter (μm):	
Cashmere	11 - 20
Guard hair	50 - 100
Range of individual fiber diameters (μm):	
Cashmere	5 - 30
Guard hair	30 - 200
Scoured yield (%)	65 - 90
Grease content(%)	1 - 10
Suint (%)	.3 - 4
Mechanical yield (% of hair-in, scoured)	15 - 90
Fiber length (in.):	
Cashmere	.5 - 3.5
Guard hair	2 - 8
Medullation (%)	
Cashmere	0 - 3
Guard hair	>90
Color	White, tan, brown, gray, black
Style and character	Cashmere (cashgora, mohair)

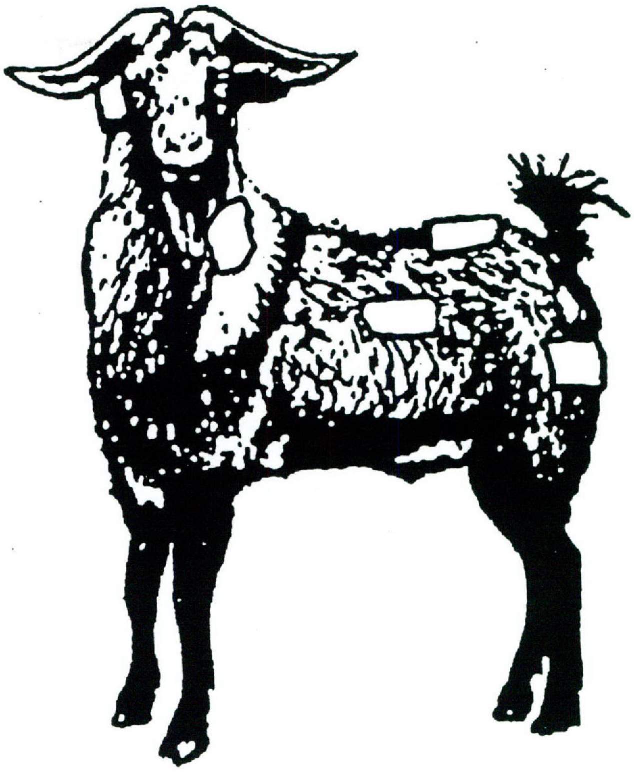

Figure 1. Sampling locations for Cashmere goats.

For yield and diameter determination, 5 oz. is an adequate sample size. Because variation in diameter and yield does exist between different body areas, other sampling points that may be considered are the neck, back, and britch. However, if the fleece is shorn, by far the best way to sample a whole fleece is to spread it out and take samples with the assistance of a grid. This ensures impartiality on behalf of the person doing the sampling and the sample thus taken has the potential to provide accurate yield, diameter, and staple length data representative of the whole fleece. When samples are taken to evaluate an individual goat, it is very important that the age of the animal be recorded at the time of the sampling. Cashmere goats produce progressively coarser fibers with increasing age. Time of sampling should also be noted because the mean diameter of growing down fibers decreases up to shedding time (8).

Objective Measurements

Scoured yield. The methods (1,12) involve scouring samples in hot, soapy water followed by determination of residual grease, inorganic ash, and vegetable matter content (2) on the dried, scoured fiber. Subsequently, "cashmere base" (pure, oven-dry fiber) is converted to a value known as "cashmere fiber present" by dividing with a factor of 0.86 (in the case of the U.S. method). This is the factor required to adjust the cashmere base to a moisture content of 12 percent, an allowable alcohol-extractives content of 1.5 percent, and a mineral matter content of 0.5 percent.

Mechanical yield of cashmere. In contrast to the scoured yield, this yield reflects the proportion of fine cashmere fibers that can be mechanically separated from coarse guard hairs. This value can be accurately assessed using tweezers to separate the two types of fibers followed by weighing of the separated portions using an analytical balance. This very slow procedure has been replaced in commercial labs by the Shirley Analyzer Mk. II Wool Model, which uses a carding aerodynamic principle to separate guard hair from cashmere in a relatively short time (6, 7). As a sample of damp, scoured cashmere is passed through this machine, guard hairs are progressively removed from the bulk. Multiple passages (now standardized at six) are required to remove a high proportion of coarse hair.

Diameter. A microprojection technique for determining average diameter has been the international industry standard for many years. In ASTM and IWTO standard methods (ASTM, 1990d, and IWTO, 1961) short longitudinal sections are projected onto a screen using standard magnification of 500X. The widths of the projected images are measured in microns (µm; 1 µm = 10^{-6} meter) using a standard wedge card or ruler. These methods allow for calculation of both an average and a measure of variability of diameter, either the standard deviation or coefficient of variation of diameter. Using the wedge card technique, a competent technician can measure 200 fibers in about 20 min.

To obtain ±0.2 µm confidence limits of the mean at the 95 percent probability level when measuring cashmere (17 µm), it is necessary to measure about 1,500 fibers. However, since cashmere is so fine and uniform, a reasonable indication of diameter (±0.4 µm) can be obtained by measuring only 400 fibers. Fiber diameter measurements are often summarized in the form of a histogram. Several U.S. institutions are experimenting with digitizing devices (9) that could replace the wedge card or ruler and allow for more rapid measurement. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Fiber Fineness Distribution Analyzer (13, 16) and its commercial counterpart, the Peyer Texlab FDA 200 System, represent an innovative concept for determining animal fiber fineness parameters. Commercially, the instruments are used to measure dehaired cashmere in Australia and New Zealand. The electro-optical technique can measure 1,000 fibers, calculating a mean, standard deviation, and coefficient of variation and printing this information together with a histogram, all in the space of 3 min. The Peyer Texlab FDA 200 System is programmed to measure fiber diameters in the range of 6 to 80 µm. Thus, it is not capable of measuring all the guard hairs.

Difference in diameter between cashmere down and guard hair. Mechanical separation of down and guard hair is virtually impossible if the mean diameters of these two fiber populations are not separated by a significant amount (i.e., 30 µm). Thus, this is a critical parameter whether selecting goats for breeding or purchasing raw cashmere for processing.

Staple length. Commercially, mean fiber length determines the system on which the fiber will be spun (worsted or woolen) and the type of product into which the fiber will be manufactured. The standard U.S. technique for determining staple length (3) is simple, accurate, but slow and requires only a ruler for measurement and a pencil for recording. This method can easily be adapted for direct measurements on the live animal.

Medullation. Projection microscopy is used in the two standard methods (5, 11) for determining the percentage of medullated fibers in cashmere. Fibers are prepared in exactly the same manner as for diameter determination. However, only a cursory inspection of the projected fibers is required to designate individual fibers either medullated or non-medullated.

Subjective Characterization

Style and character. Style is usually defined as the twist in a staple. Character is the crimp or wave. No current ASTM method addresses the measurement of style or crimp. Nevertheless, style and crimp of relaxed cashmere staples can be (painstakingly) quantified using a felt board and a ruler. Visual appraisal of style and character forms an important part of purchasing strategy. The character of cashmere must be correct for a buyer to purchase it as such. Desirable cashmere style/character involves irregular crimp of small magnitude and high frequency that changes planes at random points along the length of individual fibers. Without cashmere character, the fibers have the appearance of super-fine mohair (loaded with kemp) or cashgora down.

Luster. Luster (a prized characteristic of mohair) is routinely and subjectively assessed in the marketing process. The best Chinese cashmere has no luster. Some of the cashmere produced in the U.S. and in Australia exhibits low to medium luster. Although this type of cashmere can be truly fine and aesthetically pleasing, luster in cashmere is usually interpreted (by buyers) as being indicative of Angora influence and, therefore, coarse fibers.

Color. Scoured color is a reproducible, measurable characteristic of cashmere. A colorimeter could be used to accurately specify the color of scoured cashmere. However, classing of cashmere into color lines is traditionally achieved subjectively.

Cashmere Goat Research Conducted by the Texas Agricultural Experiment Station

Since the initiation of cashmere research at San Angelo in 1988, the Texas Agricultural Experiment Station has maintained a flock of cashmere-producing goats. The flock currently numbers about 60 does and their offspring. The flock began with Spanish does that had been visually selected for cashmere production. Production parameters are shown in Table 2. Some of these animals were artificially inseminated using semen from selected Australian and New Zealand cashmere billie goats. Subsequently, selected domestic Spanish billies have been used. The doe flock has been evaluated each year since 1989 for fleece weight, fiber diameter, and cashmere yield. Breeding objectives for the flock have included increasing fleece weight and yield while maintaining fiber diameter below 17 µm.

A study conducted in 1989-1990 compared fiber production traits of Angora, Angora x Spanish, Cashmere x Spanish, and Spanish goats (8). Fleece weights, yield, and diameter were measured for all groups. Angora goats produced the highest mean fleece weights, followed by Angora x Spanish, Cashmere X Spanish, and Spanish, respectively.

It is known that for sheep and Angora goats, mean fiber diameter can vary considerably on different parts of the body. In December 1990, an experiment was undertaken to determine if this was also the case with cashmere goats. Shoulder, side, and thigh samples were measured for 28 nanny kids and 22 billie kids. Cashmere appears not to vary as much among body locations compared with mohair from Angora goats. The 50 animals in the study averaged only about 0.5-µm difference between body locations in mean fiber diameter. For the nanny kids, the samples from the thigh were slightly coarser than those from the shoulder and side. For billy kids, the side samples was finest, followed by thigh and shoulder.

Performance Testing of Cashmere Billie Goats

Performance testing of stud animal prospects has long been used to identify genetically superior animals. In 1991, a Cashmere and Meat Goat Performance Test was initiated at the Texas Agricultural Experiment Station in San Angelo (19). A total of 150 animals belonging to 26 breeders were tested in either "meat-only" or "meat plus cashmere" categories. The test ran from June to December 1991. The billies in the meat-only group were evaluated for initial and final weight, average daily gain in feedlot and on pasture, muscling score, and cashmere score. In addition to the above traits, animals in the meat-plus-cashmere group (108) were evaluated for fleece weight, cashmere diameter, estimated cashmere yield, estimated weight of cashmere produced, staple length of cashmere, staple length of guard hair, and average testes circumference. Further, the animals were scored for style and character and cashmere cover score. Because of the wide variation in age and size of the animals on this first test, no index was used to rank the billies. Mean values for measured traits of billies in the meat-plus-cashmere group are shown in Table 3.

Phenotypic correlations between the 11 traits measured or estimated during this test are summarized in Table 4. As expected, undesirable positive correlations exist between fiber diameter and cashmere yield, fleece weight, staple length, and cover. However, as fiber diameter decreases, style and character tend to improve.

Future Research Plans

We plan to develop automatic image analysis for measurement of fiber diameter and mechanical yield. Near-infrared spectrometry will also be investigated for the same purposes. In addition, we will continue to upgrade the cashmere doe flock by breeding to highly selected cashmere billies. It has been suggested that the Cashmere Billie Goat Performance Test be continued, but its future at the San Angelo location is not certain at this time.

Table 2. Production parameters for TAES cashmere goat flock.

Year	No. Does	Fleece wt. (lb)	Diameter (µm)	Estimated mechanical yield (%)
1989	47	.47	16.85	27
1990	53	.62	19.36	24
1991	45	.53	17.55	26
1992	60	.58	16.98	

Table 3. Mean values for traits measured or scored in the 1991 Cashmere Billie Performance Test (meat-plus-cashmere group only).

Trait	Mean value
Initial weight (lb)	58
Final weight (lb)	88
Average daily gain, pasture (lb)	.09
Average daily gain, feedlot (lb)	.34
Fleece weight (lb)	.69
Cashmere diameter (µm)	17.1
Estimated cashmere yield (%)	33.0
Staple length, guard hair (in.)	2.39
Staple length, cashmere (in.)	1.84

Table 4. Phenotypic correlations between the traits measured or scored in the 1991 Cashmere Billie Performance Test.

	Final wt	Total gain	Fleece wt	Cash. diam.	Est. yield	Cash-mere wt	Staple length (cash-mere)	Staple length (guard hair)	Style and char.	Cover score	Testes circum.
Init. wt	.89**	-.45**	.34**	.19	-.21*	.07	.07	.15	-.15	-.10	.38**
Final wt		.01	.33**	.19	-.19	.09	.09	.15	-.21*	-.14	-.69**
Total gain			-.10	-.03	.08	.03	.03	-.04	-.09	-.06	-.11
Fleece wt				.03	-.06	.57**	.48**	.85**	.03	.33**	.30**
Cash. diam.					.24*	.27**	.33**	-.08	-.25*	.28**	.10
Estimated yield						.75**	.47**	-.12	.02	.66**	-.06
Cash. wt							.71**	.43**	-.05	.73**	.18
Staple lgth. cashmere								.41**	.02	.70**	.18
Staple lgth. guard hair									.04	.25*	.06
Style/char.										.24*	-.08
Cover score											-.01

** Significant correlation (P<0.01). * Significant correlation (P<0.05).

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PR-4944

Changes in Wool Fiber Diameter During and After Ram Performance Testing

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Summary

Two experiments were conducted to quantify changes in wool fiber diameter during and after fine-wool ram performance testing. Overall, the wool on 257 rams completing the 1991-92 performance test coarsened by 3.34 µm with individual animals ranging from -0.44 to 8.89 µm. The fineness of wool produced during the test could not be accurately predicted using pre-test wool diameters (r = 0.50). Wool sampled in 1991 from 50 participants of 7 previous performance tests was 0.4 µm finer than when the wool was measured on test. Variable environmental conditions under which these rams had been maintained since performance testing undoubtedly contributed to the low correlation (r = 0.35) between test and post-test wool diameters.

Introduction

Since fiber diameter is the single most important factor influencing the value of wool (4, 2), it follows that this trait should be incorporated into overall assessment of fine-wool rams. Procedures for performance testing of rams in Texas have been outlined and summarized previously (6, 7). The quality of wool produced by sheep is dependent upon genetic and environmental factors.

Recognizing this, the producers have questioned the usefulness of measuring fiber diameter on rams that have been maintained under intensive feeding conditions. The major value of this measurement has been for comparison purposes, i.e., comparing the wool fineness of rams within or between performance tests. Bassett et al. (1) studied the quality of wool on performance-tested rams compared with their female offspring and concluded that the difference in sire and daughter fiber fineness averaged within the range 2.60 to 2.98 µm. Their data also supported the conclusion that fine-wool rams in a full-feed (performance-test) situation produce a fleece that is 2 to 3 µm coarser than would be produced under range conditions. Lupton and Shelton (3) reported that the average enlargement of fibers during the performance test was 1.77 µm, with most of the coarsening occurring by the middle of the growth period. Increases in fiber diameter ranged from 0.47 to 5.46 µm for individual rams measured. To obtain a better understanding of the effects of age and environment on fiber diameter of performance-tested rams, two experiments were designed to quantify the coarsening of wool during a performance test and the changes that occur in wool fineness in years following the test.

Experimental Procedure

Experiment 1. Side samples were removed from 257 rams at the beginning of the 1991-92 performance test. These samples were subsampled at the base of the staple, and the average fiber diameters were determined on the subsamples. Simple linear regression analysis was used to calculate the correlation between the reported test diameter and the diameter measured at the start of the test.

Average fiber diameters were determined on the cleansed samples using the Peyer Texlab FDA 200 System (5).

Experiment 2. Cooperators who participated in ram performance tests before 1991 were invited to send mid-side wool samples from performance-tested rams to the Wool and Mohair Research Lab in San Angelo. The breeders were also asked to provide information on how their rams had been maintained during the period between the performance test and time of sampling. Average fiber diameter was determined on all samples received. Subsequently, simple linear regression analysis was used to calculate the correlation between the reported test diameters and the fineness of the submitted samples.

Results and Discussion

Experiment 1. The average fiber diameter of pre-test wool from 257 rams was 20.07 µm (SD = 1.74 µm; minimum value = 15.80 µm; and maximum value = 26.78 µm). The average fineness of wool produced during the test was 23.41 µm (SD = 1.54 µm; minimum value = 19.61 µm; and maximum value = 27.19 µm.) The changes in wool fineness for this group of rams is represented in Figure 1. The minimum amount of coarsening was -0.44 µm (i.e., wool on one ram became finer). At the other extreme, one ram coarsened by 8.89 µm. The correlation between the two data sets was significant ($P<0.01$) but not high ($r = 0.50$). In other words, only 25 percent of the variability in the test diameters was explained by variability in the pre-test samples. Multiple linear regression analysis was used to calculate correlation coefficients for test diameter versus pre-test diameter plus initial weight, pre-test diameter plus average daily gain, and pre-test diameter plus initial weight and age. The correlation coefficients were 0.53, 0.53 and 0.56, respectively. In other words, use of age, initial weight, and average daily gain did not substantially improve our ability to predict the diameter of wool on performance-tested rams.

We concluded that for the group as a whole, pre-test side diameter is a poor predictor of actual test side diameter. For groups of rams belonging to individual breeders, the correlation coefficient for these two variables was sometimes higher (e.g., 0.69). However, even for these groups, pre-test side diameter cannot be considered an accurate predictor of actual test side diameter.

Experiment 2. Fifty samples were submitted by 14 cooperators and different units within the Experiment Station. Five maintenance conditions were identified, ranging from full feed to full-time pasture without any supplemental feed. Wool was submitted from rams that had participated in performance tests from 1985 to 1991. The average diameter of submitted samples was 22.04 µm (SD = 1.55 µm; minimum value = 18.03 µm; and maximum value = 25.15 µm). In comparison, the average diameter of samples from this group of animals as measured when they were on test was 22.41 µm (SD = 1.62 µm; minimum value = 18.72 µm; and maximum value = 26.90 µm). Differences between these diameters and submitted sample diameters ranged from -4.56 to 3.48 µm. The correlation between these two data sets was low ($r = 0.35$), as shown in Figure 2. The different ages, genetics, and post-test nutritional status of these rams obviously contributed to this low correlation. We concluded that most rams will grow finer wool after the performance test, but the extent to which fiber diameter decreases (or even increases) depends upon genetic and environmental influences and is quite variable and unpredictable ($r^2 = 0.12$) between rams.

Further experimentation is required to establish the effects of aging and specific environmental conditions on wool fineness of fine-wool, performance-tested rams.

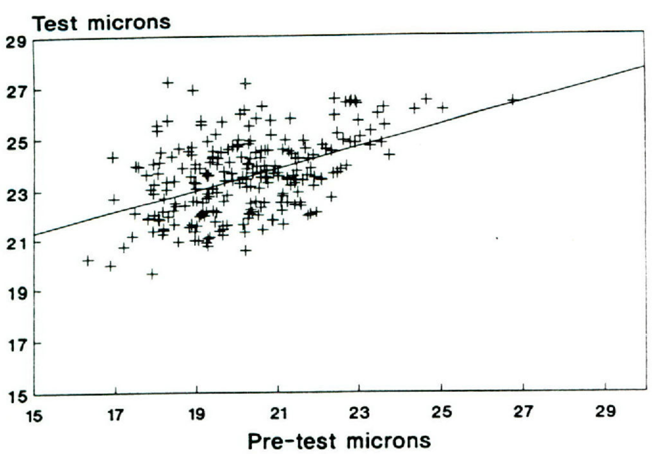

Figure 1. Pre-test versus test fiber diameters of rams in 1991-92 performance test.

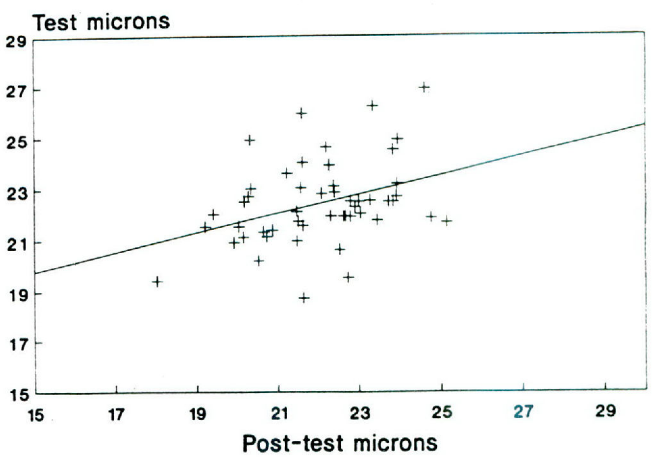

Figure 2. Post-test versus test fiber diameters of rams that participated in performance tests between 1985 and 1991.

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PR-4945

Application of Automatic Image Analysis to Animal Fiber Research

N.E. Blakeman, C.J. Lupton, and F.A. Pfeiffer

The Wool and Mohair Research Laboratory at the Texas Agricultural Research Center, San Angelo, has acquired an automatic image analysis system and is currently working in cooperation with colleagues in the Computer Science and Agricultural Engineering Departments at Texas A&M University to design software to measure mean fiber diameter. The system uses an IBM compatible computer to analyze fiber images enlarged with a microscope. Results of preliminary trials are highly encouraging.

Although image analysis measurements of mean fiber diameter and standard deviation differed slightly from those obtained using either the projection microscope or the Peyer Texlab FDA System, automatic image analysis shows promise as a precise and relatively rapid method of determining mean fiber diameter and standard deviation of wool fibers. The discrepancies in results are most likely explained by software error in identifying individual fibers, particularly in undispersed clumps. Improvements in the software's ability to recognize individual fibers should result in greater accuracy of measurement and lower standard deviations.

After perfecting the fiber diameter software, we plan to develop software that will permit automatic measurement of other parameters of interest to the wool, mohair, and cashmere industry. One area of interest is the measurement of medullated fibers in mohair. Medullated fibers are animal fibers that contain a hollow core and are classified as either med or kemp. Kemp fibers are generally very coarse and stiff and have a chalky white appearance in contrast to the transparent luster of normal mohair fibers. Kemp fibers are considered to be a serious defect in mohair because of their apparent resistance to dyeing and because of their effect on the feel and appearance of fabrics. The current standard method of determining medullated fibers uses a projection microscope. The method is fairly time-consuming and subject to operator error. Image analysis technology should lend itself well to the measurement of medullated fibers.

Another use of image analysis will be for measurement of staple length. Staple length is important to producers and manufacturers because different lengths of natural fibers have different uses and must be processed differently. The same setup could be used to measure crimps per unit length in wool and to specify lock type in mohair.

Cashmere production is becoming increasingly important to the Texas agricultural industry. After down diameter, the most important characteristic is the amount of down versus the amount of guard hair in a cashmere fleece. Image analysis techniques should be able to readily differentiate between guard hairs and down and should be capable of producing a reliable estimate of the amount of cashmere present in a fleece.

The potential advantages of Automatic Image Analysis Technology in the field of animal fiber metrology are numerous. Automatic image analysis is faster, less dependent upon individual operators, and less labor intensive than current methods that use the projection microscope. Initial cost is less, maintenance is easier, and a greater range of fiber diameters can be measured than with the FDA. It can be programmed to conform to either international or U.S. methods of measuring.

The versatility of the image analysis technology is perhaps its greatest advantage. Because one system can potentially measure multiple parameters, a savings in time and equipment investment should be realized. Image analysis systems might also be made portable so that measurements could be made in the field. Making objective measurements more readily available to the animal fiber industry will further improve marketing and selection procedures and benefit all segments of the industry. For these reasons, image analysis technology is expected to become the premier tool for objective characterization of animal fibers.

PR-4946

Performance Levels and Fleece Characteristics of Angora Goats in Western Texas

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Summary

Two hundred castrated male Angora goats (18 mo of age) were divided equally between research sites in McCulloch County (MC; Edwards Plateau) and Zavala County (ZC; South Texas Plains) for a 4-year period to study effects of location (therefore, diet and other environmental factors), season, and animal age on body weight, mohair production, and mohair fiber characteristics. The goats were grazed on rangeland typical of the respective regions and were given typical management that included shearing in February and July or August of each year. Shorn animals were weighed, and individual fleeces were characterized in terms of greasy weight, clean yield, average fiber diameter, and medullated fibers (med and kemp). Rainfall accumulations were recorded daily at both research sites throughout the study.

Overall, goats at the MC location were heavier ($P<0.05$) than those maintained in ZC (84.2 and 82.5 lb, respectively). Grease mohair production was similar at both locations (5.9 and 6.0 lb/6 mo). Yield, fiber diameter and kemp were lower ($P<0.05$) for MC than ZC fleeces (77.2 percent, 37.8 µm, and 0.62 percent versus 78.2 percent, 38.6 µm, and 0.78 percent, respectively). Mohair shorn in February was finer and contained less kemp ($P<0.05$) than summer-shorn hair (36.8 µm and 0.61 percent versus 39.7 µm and 0.79 percent, respectively). The MC goats weighed less and sheared less mohair ($P<0.05$) in winter than in summer (80.2 and 5.7 lb versus 87.3 and 6.1 lb, respectively). Conversely, the ZC goats were heavier and sheared more mohair ($P<0.05$) at the winter clip compared with the summer clip (84.5 and 6.5 lb versus 80.6 and 5.4 lb, respectively). Animals in both flocks increased in body weight and fiber diameter with increasing age ($P<0.05$). Correlations with animal age were significant for animal weight ($r = 0.92$, $P<0.01$) and fiber diameter ($r = 0.85$, $P<0.05$) for the ZC flock. Age effects were masked to some degree by environmental effects such as rainfall, which was highly variable between locations, seasons, and years. Six-month accumulations of rain were significantly correlated with mohair production ($r = 0.78$, $P<0.05$) and average fiber diameter ($r = 0.78$, $P < 0.05$) for the MC flock.

This study suggests that body weight, mohair production, and fiber characteristics are influenced by environment and/or age of goats. Production of mohair by castrated male Angora goats is quantified for two substantially different ecosystems.

Introduction

Angora goats were introduced into the United States more than 100 years ago because of their capacity to produce large quantities of white fiber (mohair). Their unique dietary preferences for foliage from trees and shrubs make the goat of greatest value on ranges where these plants are present. Competition for dietary components between goats and sheep or cattle is, therefore, somewhat less than within-species competition or competition between sheep and cattle.

Goats in the Edwards Plateau region depend heavily on "oak-type" browse, especially during winter and periods of low-moisture dormancy (7). In the South Texas Plains region, goats rely on "leguminous" browse (mostly species of acacia) and other "thorny" species (11), which are generally higher in protein than shrubs of the Edwards Plateau region (5, 10). Quality characteristics of mohair are affected by nutrient content of diet (4, 9), age of goat, and season of the year (3).

We initiated a study during the fall of 1986 to determine the long-term effects of location (therefore, diet and other environmental factors), season, and animal age on body weight, mohair production , and mohair fiber characteristics in Angora mutton goats.

Experimental Procedure

Two hundred male goats (18 mo of age) were selected from a flock of 1,200 that had been previously maintained together on a ranch in Crockett County, Texas. The animals were castrated with a burdizzo, individually identified with ear tags, then randomly assigned to two groups of equal number. After shearing, one group was transported to a Texas Agricultural Experiment Station (TAES)-leased property in McCulloch County (Edwards Plateau region), and the other group was shipped to a TAES-controlled ranch in Zavala County (South Texas Plains region).

The goats were grazed on rangeland typical of the respective regions and given typical management for 4 years. Rainfall was recorded daily at each site. Animals were sheared and weighed at 6-mo intervals (February and July or August). The following characteristics were measured on each fleece shorn: grease fleece weight, clean yield (1), fiber diameter and distribution (6), and medullated fiber content (2). Comparisons for location and season were made for body weight and each fleece characteristic using SAS General Linear Models Procedure (8). Duncan's Multiple Range Test was used to identify significant differences between mean values. Simple linear regression analysis was also used to quantify relationships between age and rainfall versus body weight and fleece characteristics. All animals remaining in the flock at each shearing were used in the analyses.

Results

Complete data were collected over the 4-year period for the numbers of goats listed in Table 1. During this time, 20 goats died in the MC flock, and deaths occurred throughout the study. No predation was observed in either flock. In contrast, only 47 animals survived on the ZC ranch. Attributed to guajillo poisoning, most of the deaths occurred during a 2-year period beginning in the spring of 1988.

Over the 4-year study, animal weights increased by more than 20 lb, and considerable between-season fluctuation occurred after the animals attained maturity (Table 2). The small discrepancy between initial weights was probably due to the animals' being weighed at slightly different times, after different length journeys, and in different degrees of shrink. Overall, the MC animals maintained a slightly higher body weight (84.2 lb) than the ZC animals (82.5 lb). Other effects of location are summarized in Table 3. Grease fleece production was almost identical for the two locations although ZC fleeces yielded slightly higher than MC fleeces (78.1 versus 77.2 percent). Fleeces produced in ZC also tended to be slightly coarser (38.6 versus 37.8 µm) and contained marginally more kemp (0.78 versus 0.62 percent) than their MC counterparts.

Table 1. Survival of Angora goats at two study locations.

Month	Year	Time (mo)	Goats, no. McCulloch Co.	Goats, no. Zavala Co.
Aug	1986	0	100	100
Feb	1987	6	97	98
Aug	1987	12	95	97
Feb	1988	18	92	92
Aug	1988	24	89	79
Feb	1989	30	85	72
Aug	1989	36	83	51
Feb	1990	42	82	50
Aug	1990	48	80	47

Table 2. Animal weights over time at two locations.

Season, yr	Animal age (yr)	Animal weight (lb) McCulloch Co.	Animal weight (lb) Zavala Co.
Fall 1986	1.5	66.5^{d}	65.5^{e}
Spring 1987	2.0	69.0^{d}	73.1^{d}
Fall 1987	2.5	81.5^{c}	82.5^{c}
Spring 1988	3.0	82.5^{c}	83.9^{c}
Fall 1988	3.5	84.7^{b,c}	84.8^{c}
Spring 1989	4.0	83.2^{c}	94.0^{b}
Fall 1989	4.5	107.3^{a}	101.0^{a}
Spring 1990	5.0	88.3^{b}	95.1^{b}

a,b,c,d,e Column values with different superscript letters differ ($P<0.05$).

Analyses were also conducted to determine the effects of season on the measured traits and are summarized separately in Tables 4 and 5. For both locations, fleeces shorn in February were finer than those shorn in August. This difference was more pronounced for MC fleeces. In addition, fall fleeces contained significantly more kemp than spring fleeces, but yield values for both locations and seasons were almost identical. In contrast, seasonal effects on animal weight and fiber production were quite different for the two locations. In the MC flock, animals were invariably heavier (87.3 versus 80.2 lb) and produced more mohair (6.1 versus 5.7 lb) at the fall clip compared with the spring clip. The opposite situation existed in ZC, where animals were heavier (84.5 versus 80.6 lb) and sheared more mohair (6.5 versus 5.4 lb) in February compared with July or August. The seasonal effects observed for MC are generally true for production across the Edwards Plateau. Typically, a November frost eliminates most of the green nutrition composed of grasses, forbs, and shrubs, though liveoak leaves that are rather low in digestibility persist.

Table 3. Location effects on body weight, mohair production, and fiber characteristics.

Location	Animal weight (lb)	Grease fleece weight (lb)	Yield (%)	Average diameter (µm)	Med fibers (%)	Kemp fibers (%)
McCulloch Co.	84.2^{a}	5.9	77.2^{b}	37.8^{b}	1.23	.62^{b}
Zavala Co.	82.5^{b}	6.0	78.2^{a}	38.6^{a}	1.25	.78^{a}

a,b Column values with different superscript letters differ ($P<0.05$).

Table 4. Seasonal effects on body weight, mohair production, and fiber characteristics of goats maintained in McCullouch County.

Month fleece shorn	Animal weight (lb)	Grease fleece weight (lb)	Yield (%)	Average diameter (µm)	Med fibers (%)	Kemp fibers (%)
February	80.2[b]	5.7[b]	77.0	35.7[b]	1.46[a]	.49[b]
August	87.3[a]	6.1[a]	77.4	40.0[a]	.99[b]	.75[a]

[a,b]Column values with different superscript letters differ (P<0.05).

Table 5. Seasonal effects on body weight, mohair production, and fiber characteristics of goats maintained in Zavala County.

Month fleece shorn	Animal weight (lb)	Grease fleece weight (lb)	Yield (%)	Average diameter (µm)	Med fibers (%)	Kemp fibers (%)
February	84.5[a]	6.5[a]	77.9	38.0[b]	1.18	.74[b]
July/ August	80.6[b]	5.4[b]	78.4	39.4[a]	1.33	.84[a]

[a,b]Column values with different superscript letters differ (P<0.05).

Relatively low-quality feed is available throughout the winter months up to shearing in February. Subsequently, spring rains and warmer temperatures usually generate an abundance of plant nutrition of relatively high nutritive value, which permits the animals to gain weight and produce more mohair than in the previous season. A major production variable in this period is the point at which summer heat and lack of moisture cause the range to dry out and nutritive values of plants to decline. Generally, goats in the Edwards Plateau region have access to more and better-quality feed in the period between March and August than in September to February. This is reflected in animal and fleece weights. The reverse appears to be true at the ZC location. The cooler days of fall provide good growing conditions for the acacia species that predominate in this area. Foliage on these plants in unaffected by mild frosts and sometimes persists throughout the winter, providing Angora goats with ample nutrition. In contrast, the dry, hot conditions predominating from late spring through the summer severely restrict new growth on these shrubs and consequently availability of nutrients for the goats declines. Thus, goats in ZC tend to weigh more and produce more mohair during the fall/winter seasons than in spring/fall. However, aberrations from this general trend occur when atypical, favorable moisture conditions occur during summer. The fall weight of 1989 (Table 2) serves as an example.

Simple linear regression analysis was used to calculate correlation coefficients for the seasonal means of animal weight, fleece weight, and fleece characteristics versus age. Table 6 shows the results of this analysis. Animal weight and age were significantly and positively correlated at both locations. For the ZC flock, average diameter and age were also highly correlated (r = 0.85, P<0.01). Low correlation between age and other properties is considered to be a result of uncontrolled environmental influences. Effects of rainfall were singled out for further analysis.

Correlation coefficients were calculated for rainfall accumulations versus animal weight, fleece, and fiber properties (Table 7) for both locations. Although several different accumulation periods were tested, February through July and August through January versus traits measured for the respective fiber-growing periods produced the highest correlation coefficients. Two significant r values (P<0.05) were noted in the MC data, indicating a reasonable correlation between seasonal rainfall accumulation and grease fleece weight and fiber diameter. Similar correlations were not noted for the ZC flock, probably indicating a more random rainfall pattern in ZC compared with MC.

Table 6. Correlation coefficients for age versus mean values of animal weight and fleece properties.

Age versus:	McCulloch Co.	Zavala Co.
Animal weight	.81*	.92**
Grease fleece weight	-.53	-.07
Yield	.68	.12
Average diameter	.65	.85**
Med fibers	-.18	.32
Kemp fibers	.24	.24

* Significant correlation (P<0.05).
** Significant correlation (P<0.01).

Table 7. Correlation coefficients for rainfall accumulation versus mean values of animal and fleece weights and fiber properties.

Rainfall (accumulation periods: (Feb.-July and Aug.-Jan.) versus:	McCulloch Co.	Zavala Co.
Animal weight	.50	-.55
Grease fleece weight	.78*	.18
Yield	-.63	-.22
Average diameter	.78*	.47
Med fibers	-.43	.74*
Kemp fibers	.48	-.48

*Significant correlation (P<0.05).

Conclusions

Guajillo poisoning of Angora muttons was obviously a serious problem on the ranch in ZC in the South Texas Plains region. The problem appeared to be accentuated during drought when forage from other sources was not available. Analyses of accrued data on the surviving animals at the MC and ZC locations indicate:

1. Differences in body weight, yield, fiber diameter, and kemp between the two research sites were significant (P<0.05), but very small.

2. Grease mohair production over the 4-year period was almost identical for the two locations.

3. Mohair shorn in February was finer and contained less kemp (P<0.05) than summer-shorn hair.

4. Animals in both flocks increased in body weight and fiber diameter with increasing age. Age effects were probably masked to some degree by environmental influences such as rainfall.

5. Effects of rainfall on mohair production and fineness were more predictable at the MC compared with the ZC location.

6. Seasonal effects on body weight and mohair production existed but were in reverse order for the two locations.

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PR-4947

Feedlot Performance and Carcass Measures of Rambouillet and Rambouillet x Australian Merino Cross Wethers

T.D. Willingham, M. Shelton, P. Thompson, and G. Snowder

Summary

Rambouillet, strong-wool Merino x Rambouillet, and fine-wool Merino x Rambouillet wether lambs were evaluated for feedlot performance, carcass quality, and yield. No significant differences were found between breed types for average daily gain, feed to gain ratios, carcass quality grade, or yield. However, Rambouillet lambs tended to gain more readily and yield higher cutting carcasses. Fine-wool Rambouillet cross lambs had more backfat (P<0.05) and more kidney and pelvic (KP) fat (P<0.05) than Rambouillets and tended to have lower yielding carcasses. All breed types averaged Choice minus quality carcasses.

These data represent a subset of a much larger trial being conducted with three cooperating states and represent only those lambs produced in Texas.

Introduction

In recent years producers have shown some interest in the potential for improving fleece traits, particularly fleece yield and clean wool weight by crossing Australian Merinos to domestic breeds, primarily Rambouillets. The level of interest in improved wool production may continue and will be greatly influenced by the price received for lamb. Although the interest in Australian Merinos stems from their fleece characteristics, producers in this country must also have information on their influence on ewe reproductive rates and the value of the market lamb.

A cooperative multi-state project was initiated to provide data on these points. This report provides data from one station (Texas) on the feedlot performance and carcass traits of Rambouillet and Rambouillet x Australian lambs.

Experimental Procedure

The study consisted of 160 wether lambs subdivided into three breed types or groups. Lambs were produced at the Winters Ranch near Brady, Texas. The breed types were Rambouillet (n = 46), Australian strong-wool Merino x Rambouillet (58), and Australian fine-wool Merino x Rambouillet (56). Numbers of lambs in each breed varied because of availability of lambs. All lambs were shorn and drenched before placement on feed. Some lambs were slaughtered shortly after being placed on feed. For this reason, feedlot data are reported for only 103 lambs that remained on feed for at least 82 days. Each breed type was divided further into sire groups and fed ad libitum. Lambs were fed a 13.7 percent crude protein and 1.46 Mcal DE/lb diet based on sorghum grain and peanut hulls. Fresh feed was added daily, and weekly consumption records were collected. Animals were maintained on feed until they reached slaughter weights. Slaughter weights were varied intentionally within groups to permit an evaluation of the optimum slaughter weight for each group. However, an attempt was made to establish an equivalent mean carcass weight among groups. All animals were on feed before slaughter; however, time on feed varied between animals because an attempt was made to slaughter animals within a predetermined weight range. In addition, lambs were either group fed in a large lot or in smaller pens divided into sire groups.

For analysis, sire groups were pooled into breed types. Analysis of variance using the general linear models procedure SAS (1) was conducted to test for breed-type differences. Tukey's least significant difference was used to test for differences between means. Linear regression was used to adjust carcass measures to a common carcass weight.

Results and Discussion

Body weights and average daily gains are given in Table 1, and feed per pound of gain is listed in Table 2. These data are presented separately because consumption data were obtained for sire groups; whereas, gain data were collected for individual animals. Rambouillet lambs were heavier ($P<0.05$) than strong-wool crosses initially and at the end of the trial.

Differences in daily gains were not statistically significant, but the trend did tend to favor the Rambouillet lambs. Differences in feed efficiency (lb feed/lb gain) are not statistically significant.

Actual carcass measurements are shown in Table 3. Rambouillet lamb carcasses were heavier ($P<0.05$) than the strong-wool Merino cross lambs. Carcass weight was correlated with backfat thickness ($P<0.01$), percentage of KP fat, and leg muscling scores ($P<0.01$). Therefore, these carcass measurements were adjusted to the mean carcass weight of 59.4 lb. Adjusted values are shown in Table 4.

Fine-wool Merino cross lambs carried more backfat than either Rambouillet or strong-wool cross lambs; however, the difference was significant only for the comparison of fine-wool versus strong-wool Merino x Rambouillet. In addition, fine-wool crosses tended to have a greater percentage of KP fat, resulting in lower yielding carcasses. All lambs had adjusted leg conformation scores equivalent to average Choice and quality-graded Choice minus.

Table 1. Mean body weights and daily gains of Rambouillet and Rambouillet cross wethers (82-day trial).

Breed	n	Initial[a] body weight (lb)	Final[a] body weight (lb)	Average[a] daily gain (lb)
Rambouillet	34	64.3[a]	99.4[a]	.428[a]
Strong-wool x	27	59.0[b]	90.7[b]	.387[a]
Fine-wool x	42	60.3[ab]	93.5[ab]	.405[a]

[a]Means within columns without a common letter superscript are significantly different ($P<0.05$).

Table 2. Mean feed efficiency (lb feed/lb gain) of Rambouillet and Rambouillet cross wethers (82-day trial).

Breed	Number sire groups	Number lambs	Feed/gain
Rambouillet	6	34	7.84[a]
Strong-wool x Rambouillet	5	27	7.74[a]
Fine-wool x Rambouillet	6	42	7.78[a]

Table 3. Mean carcass measures of Rambouillet and Rambouillet cross wethers.

Breed	n	Carcass[a] weight (lb)	Backfat[a] (in.)	KP[a] fat (%)	Leg[ab] score	USDA[ab] Quality grade	USDA[ab] Yield grade
Ramb.	46	60.8[a]	0.20[a]	2.65[ab]	12.2[a]	10.4[a]	3.09[a]
S-wool x Ramb.	58	58.2[b]	0.21[a]	2.25[a]	11.9[a]	10.2[a]	3.05[a]
F-wool x Ramb.	56	59.4[ab]	0.24[a]	3.13[b]	11.8[a]	10.4[a]	3.44[a]

[a]Means within columns without a common letter superscript are significantly different ($P<0.05$).
[b]Leg conformation and quality grade values are described as follows: 10 = Choice minus, 11 = average Choice, 12 = Choice plus.

Table 4. Mean carcass measures adjusted to a constant carcass weight.

Breed	n	Carcass weight (lb)	Backfat[a] (in.)	KP[a] fat (%)	Leg[ab] score
Rambouillet	46	59.4	0.20[a]	2.50[a]	11.99[a]
Strong-wool x Ramb.	58	59.4	0.22[ab]	2.37[a]	11.98[a]
Fine-wool x Ramb.	56	59.4	0.24[b]	3.12[a]	11.82[a]

[a]Means within columns without a common letter superscript are significantly different (P<0.05).
[b]Leg conformation scores are equivalent to 11 = average Choice, 12 = Choice plus.

These data indicate minimal differences in feedlot performance or carcass measures for the three breed types evaluated. Rambouillet lambs tended to gain better and produce less backfat. These data appear to indicate that crossing to either type of Australian Merino will not improve feedlot performance or carcass value over Rambouillet lambs. However, if an important advantage is realized in other traits such as wool production, the Australian Merino cross lambs can be used to produce a type of carcass that will reach an acceptable grade for the U.S. market (Choice). These data also indicate that the fine-wool Merino crosses are a smaller type of animal and should be slaughtered at a lighter weight.

Acknowledgment

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PR-4948

An Analysis of Factors Affecting Sale Price of Performance-Tested Rambouillet Rams

Maurice Shelton, N.E. Blakeman, C.J. Lupton, and D. Spiller

Summary

A total of 2,000 rams completed the performance test at the Texas Experiment Station at Sonora in the 6-year period, 1987-1992. Of these, 255, selected from the larger group according to performance data, have been sold at public auction.

This study was conducted to compare the selected (sale-eligible) rams to the non-eligible rams, and to investigate the relationship between performance data and price. The selected animals (based on index) were superior in essentially all traits measured, but the difference tended to be non-significant for belly covering and testes size and in the wrong direction (non-significant) for skin fold score. The ability to predict sale prices from performance data were lower than expected and lower than for a 6-year period ending in 1981. The buyers tended to place greater emphasis on certain traits than is explained by index value. The traits realizing greater emphasis were staple length, fiber diameter, and body size. The trait with less-than-expected relationship to price was any measure of fleece weight.

Introduction

A performance-testing program for rams has been carried on at the Texas Agricultural Experiment Station at Sonora for more than 40 years. Although the test is open to all breeds of sheep, most of the rams have been from the Rambouillet breed. Both registered and non-registered rams are included.

The report for each year's test is released at a field day in March of each year. This report provides information on procedures and detailed performance data on the rams for that particular year. Surplus copies of some of these reports are available, and copies may be obtained by contacting one of the authors. A number of review papers and reports on this program have been prepared. The most extensive was that of Shelton and Lewis (1), which covered results and experiences to 1986. A previous analysis was also made to investigate the relationship of performance data and sale price (2). This latter study covered the period 1976 to 1981 and showed a significant correlation between performance data and price for most of the traits measured. Exceptions to this were yield, fiber diameter, belly wool score, and birth type. Although statistically significant, the correlations were in most cases of low magnitude. The two traits most closely correlated to price were final weight (0.49) and index value (0.39). Because market conditions and breeder interests change from time to time, this question was re-evaluated using the period 1987 to 1992.

Procedure

The test procedures have been described in earlier reports. Basically, these consist of maintaining nominated rams in a uniform management system for 140 days. The data collected include body weights and body weight gains, fleece data, as well as score for face and belly coverings and body folds. After the data are collected, an index is calculated for each ram according to the following general formula:

> I = 60 x [daily body weight gain in lb] + 4 x [staple length in inches with no credit above 5.5 inches] + 4 x [12-mo clean fleece weight adjusted for initial body weight] -3 x [face cover score (no credit for less than 1)] - 4 x [skin fold score] with ± fiber diameter and variability points according to the following schedule:
>
> Fiber diameter on side:
>
> - 3 for each μm (micron), or fractional value above 22.9 μm
> + 3 for each μm (micron), or fractional value below 22.0 μm
>
> Variability (britch diameter as compared to side):
>
> - 2.5 for each μm (micron) the britch was coarser than the side with no advantage if the britch was finer than the side.

The clean fleece weight used in calculation of the index was that referred to as "adjusted clean fleece weight." This was done to partially correct for the contribution of differences in size or initial weight on clean fleece weight. A regression coefficient, obtained by the regression of clean fleece weight on initial weight, was used to adjust clean fleece weight to the mean body weight.

The actual index used has varied slightly over the period of this study, but the only significant change was that actual body weight gain, instead of total gain (fleece included), was used in the last 2 years.

During the period of this study, animals eligible for sale at public auction have been the top 30 percent based on the index, less some animals that were sifted by a committee or those that failed to meet certain minimal culling levels. In addition, inclusion in the sale has been at the option of the owner, and many are maintained by the owner as breeding rams and are thus not included in the auction. The number completing the test, the number eligible for sale, the number actually sold, and the average price received are shown in Table 1.

The selection procedure was evaluated by comparing the means for various traits for those animals eligible for sale compared with those not eligible for sale. Correlation studies and stepwise regression procedures were used to evaluate the relative relationship or contribution of the various traits to sale price.

Table 1. Number of rams tested, number sold at auction, and average price for period 1987 to 1992.

Year	No. animals completing ram test	No. animals eligible for sale	No. actually sold at auction	Average price received ($)
1987	303	68	42	844.76
1988	421	113	52	601.92
1989	343	80	45	627.78
1990	368	77	45	796.67
1991	314	57	36	688.89
1992	251	51	35	872.86

Results and Discussion

The difference between sale-eligible animals compared with those not eligible for sale are shown in Table 2. For the most part, the differences are significant and in the right direction. The differences in final body weight; average daily gain; grease, clean, and adjusted clean fleece weights; staple length; fiber diameter; face covering; and index value were significantly different for all 6 years. Differences in fiber diameter and face cover score are negative, as desired. All these traits are in the present index except for final weight. In this case, weight is correlated to some other factors that are in the index. Yield (%) and belly cover score were significantly different in only 3 of the 6 years. Remember that neither of these are in the index. Fold score, even though it is in the index, was not significantly different in any of the years. The negative component in the index selecting against fold score is of a low magnitude, and the variability in this value is now small. Differences in testes circumference were significant in 3 of the 6 years. This character is not in the index, and the differences observed are probably explained through its relationship to other traits, such as final weight.

Data used in the index equation contribute to the selection procedure but do not provide information on how producers or purchasers may view the relative importance of the various traits. To study this, correlation values were calculated for the relationship of various traits to sale price, as shown in Table 3.

These correlation coefficients are highly variable between traits and years. In a large measure, this should be expected because of the large number of variables involved, the fact that both buyers and market conditions vary between years, and each trait may enter the picture (may influence price) through two pathways, i.e., through its contribution to the index or by direct emphasis by the purchaser.

The values showing the most consistent relationship to price are index value and its derivative, index ratio. This relationship was significant in each year except for 1988. This should probably be expected because index

Table 2. A comparison of performance traits for sale-eligible versus non-sale-eligible animals (S - NS differences).

	1987	1988	1989	1990	1991	1992
Initial weight (lb)	5.70*	1.30*	-7.80*	-3.90	-3.00	2.00
Final weight (lb)	16.60*	15.40*	3.60	9.00*	7.90*	14.00*
ADG (total)	.079*	.102*	.082*	.090*	.078*	.086*
ADG (body)	—	—	.079	.085*	.070*	.075*
Grease fleece wt (lb)	3.99*	3.51*	2.04*	2.81*	2.77*	3.93*
Clean fleece wt (lb)	2.18*	2.11*	1.03*	1.83*	1.72*	2.36*
Adjusted clean fleece wt (lb)	2.01*	2.07*	1.29*	1.90*	1.80*	2.31*
Yield (%)	1.10	1.30*	.04	1.55*	1.11	1.51*
Staple length (in.)	.047*	.50*	.50*	.56*	.56*	.50*
Side diameter (μm)	-.60*	-.74*	-1.19*	-1.11*	-.91*	-.85*
Britch diameter (μm)	-.84*	-1.00*	-1.85*	-1.58*	-1.78*	-1.77*
Face score	-.25*	-.33*	-.23*	-.13*	-.30*	-.25*
Belly score	-.10*	-.13*	-.07	-.10	-.17*	-.12
Folds	.01	.05	-.01	.04	.04	.10
Testes	.82*	.88*	.35	.44	1.06*	.39
Index	16.08*	17.38*	16.86*	17.98*	17.10*	20.06*
Index ratio	16.54*	17.79*	18.10*	19.29*	17.83*	23.33*

*Statistically significant at the 0.05 level of probability or greater.

Table 3. Correlations between individual traits and sale price at auction.

Trait	1987	1988	1989	1990	1991	1992	Average
Initial weight	-.005	.101	.029	.253*	.270	.344**	.165
Final weight	.272*	.062	.236	.362**	.208	.242	.230
ADG (total)	.500***	-.018	.433***	.256*	-.071	-.135	.161
ADG (body)	—	—	.428***	.243	-.112	-.157	.101
Grease fleece wt (lb)	.125	-.016	.163	.075	.490***	.221	.176
Yield (%)	-.046	-.052	-.151	.152	.161	-.109	-.008
Clean fleece wt (lb)	.088	-.048	.090	.189	.539***	.193	.175
Adjusted clean fleece wt (lb)	.094	-.072	.092	.123	.495***	.120	.142
Staple length	.370**	.395***	.207	.283*	.630***	.463***	.391
Side diameter	-.251	-.517**	-.185	-.392***	-.069	-.372**	-.298
Britch diameter	-.244	-.430***	-.080	-.215	-.170	-.379**	-.253
Face cover	-.294*	-.314**	-.021	-.057	-.245	-.234	-.194
Belly score	.095	.115	.377**	-.187	-.068	-.181	.025
Fold score	-.146	-.307**	-.181	-.240	-.047	-.056	-.163
Testes	.388**	.007	.284*	.272*	.047	.230	.205
Index	.656***	.101	.600***	.563***	.542***	.306*	.461
Index ratio	.656***	.101	.600***	.562***	.542***	.306*	.461

Correlation significant at ** = 0.05 level; *** = 0.01 level.

represents the composite value, which, theoretically, is an overall estimate of genetic merit, and also that index value or ratio determines sale order.

The second most important variable contributing to price (based on average values) is staple length, which was statistically significant in 5 of 6 years. This contribution appears to be more important than the contribution of this trait to the index would suggest. This appears to indicate that purchasers are selectively emphasizing staple length.

The trait or traits having the next most important contribution to price appear to be some measure of fiber diameter, but this appears to be highly variable between years. The highest correlation between fiber diameter and price was in 1988. The sale on this date was preceded by a discussion highlighting the contribution of diameter to price received for wool. It appears that purchasers were responding to the information presented or to their prior awareness of this information. A highly significant correlation between diameter (negative) and sale price of rams was also noted in 1992. It may well be that this is in response to a period of low lamb prices, and thus a relatively higher percentage of income from wool.

In 3 of the 6 years, some measure of weight was significantly related to price, suggesting that producers are still looking for the biggest. Surprisingly, fleece weight was significantly related to price in only one year (1991). It may be desirable to increase the component favoring fleece weight in the index to force more emphasis on this trait. Other traits significantly correlated with price include face cover, belly cover, fold score, and testes size. These are all in the preferred direction except for a significant correlation between belly score and price in 1989, but on average, this relationship is very small.

Another approach to evaluating the traits that contributed to price is a stepwise regression approach. The results of this analysis are shown in Table 4. Index values were not included in these analyses, which were continued through seven variables (traits). Above this number, traits were picked up that did not make a significant contribution to price.

The most important information emerging from this exercise is that the ability to predict price from the various performance data are not highly successful.

Table 4. Results of stepwise regression analysis of variables contributing to sale price.

Number of variables in model	Variables included	R^2 (R^2 x 100 = % of variation in price accounted for in model)
1	Index ratio	.1986
2	Staple length Index ratio	.2765
3	Staple length Britch diameter Index ratio	.3343
4	Final weight Staple length Britch diameter Index ratio	.4150
5	Final weight Staple length Side diameter Folds Index ratio	.4529
6	Initial weight Staple length Side diameter Face cover Folds Index ratio	.4609
7	Initial weight Staple length Side diameter Britch diameter Face cover Folds Index ratio	.4670

Even when using seven traits, only 47 percent of the variation in price can be accounted for. This seems to indicate that other major variables are affecting price. In the previous study, it was shown that breeder name or reputation was a significant factor. No such analysis was undertaken in this study, but it seems likely that this remains a factor. Although this cannot be documented from these data, we strongly believe that physical appearance or conformation, which are not evaluated or estimated in this program, are major factors in determining price. Much of this can, no doubt, be attributed to the influence of club-lamb shows.

In the stepwise regression analysis, the factor with the greatest predictive value was index ratio, but the actual predictive value was disappointingly low. The second was staple length, strongly suggesting that this trait is being emphasized to a greater degree than is the case in the index. The third factor to enter the model was some measure of fiber diameter. Since britch and side diameter are highly correlated, it makes little difference which is used, but in the model employing seven variables, both measures were present. The fourth factor to enter the model was some measure of body weight. In the model using four and five variables, this was final weight, but in the model using six and seven variables, this was initial weight. The two weights are highly correlated, but there may still be some explanation for this shift. The fifth trait to enter the model was skin fold score and the sixth was face covering score, both of which are in the index, but which are minor factors in the index. Purchasers appear to be placing some emphasis on these above their contribution to the index. In the seven variable model, both britch and side diameter enter the model. This appears to suggest that both values may be receiving some emphasis by buyers.

Conclusions

The ability to predict sale prices according to performance data was less in the period 1987 to 1992 than for a similar 6-year period ending in 1981. Buyers appear to be placing emphasis on some traits other than that of the index. Some of the traits receiving greater emphasis were staple length, fiber diameter, and body size. By contrast, other traits, especially fleece weights, appeared to have little relationship to price.

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Correlations between Performance Data and Sale Price of Performance-Tested Angora Goats

Maurice Shelton, N. E. Blakeman, C.J. Lupton, and D. Spiller

Summary

The relationship between performance data and sale price was examined for Angora males on central performance tests for the 4 years, 1988 to 1991. Only the top 40 percent (1988) or 50 percent (1989, 1990, and 1991) based on index value were eligible for sale at public auction. Smaller percentages were actually sold at auction because some were sifted (visual inspection), failed to meet certain culling levels, or were retained by the owner for breeding. Sale-eligible animals tended to be superior in most of the traits evaluated, but the differences were not statistically significant for every trait in each year. The one exception to this generalization was in face cover score in which sale-eligible animals were not more open-faced. The trait or value having the greatest correlation with price was index or index ratio. Other characteristics showing a significant relation to price were size, character score, average daily gain, and various measures of fiber diameter and kemp percentage. The various measures of fleece weight along with yield and lock length were significantly related to price in some years, but not in all years. In the stepwise regression procedure, the traits contributing to price entered the model in the following order: index, character, some measure of weight, some measure of diameter, neck cover score, lock length, some measure of fleece weight, and kemp percentage.

Introduction

A performance-testing program for male Angora goats has been conducted by the Texas Agricultural Experiment Station at Sonora each year since 1980. A report outlining the test procedures and results is released at the end of the test each year. For readers who are interested in more details of the testing procedures, copies of some of these procedures can be obtained by contacting one of the authors. In more recent years, a public auction was held at the end of the test, and the top-indexing animals were eligible for sale. For this study, these data were analyzed (by means of correlations) evaluating the relationship of performance data to prices received at public auction for the years 1988 to 1991. These data provide information on the extent to which performance data are being used by producers in the purchase of sires, and to some extent, which traits they view as more important or which traits are more highly correlated with price. "Eligibility for sale" was based on an index of the following order, as was used for the 1991 group:

I = 4 x adjusted clean fleece weight + 25 x average daily body weight gain + 0.12 x final weight + 3 x straightened lock length - 1.5 x fiber diameter - 3 x face cover score (no credit below 1) + 2.5 x character score + 1.5 x neck cover score.

The index used contained the same components each year, but some variation occurred from year to year in the weighting of the individual traits. The index used for 1989 and 1990 was as follows:

I = 4 x adjusted clean fleece weight + 35 x average daily body weight gain + 0.15 x final weight + 2 x stretched lock length - 1.5 x fiber diameter - 3 x face cover score (no credit below 2) + 1.5 x character score + 1.5 x neck cover scores.

The following index was used in 1988:

I = 4 x adjusted clean fleece weight + 40 x average daily weight gain + 0.12 x final weight + 2 x average lock length - 1.2 x fiber diameter - 3 x face cover score + character, belly, and neck cover scores.

Eligibility for sale was based on the animal's being in the top percentage based on an index. This percentage was 40 percent in 1988 and 50 percent in 1989, 1990, and 1991. In addition to being in this top percentage, the animals must have met certain minimum levels of performance and must have passed inspection by a sifting committee. In addition to these three requirements, inclusion in the sale was at the option of the breeder. The numbers of animals in the tests, the numbers actually sold, and average prices received by years are shown in Table 1.

Table 1. Angora goat performance test and sale information.

Year	No.in test	Eligible (%)	No. sold	Avg. sale price ($)
1988	306	40	56	488.39
1989	247	50	64	859.37
1990	293	50	68	556.62
1991	255	50	57	571.93

Mean performance data for the animals sold at auction (or eligible for sale) as contrasted to those not eligible for sale were compared to indicate the extent to which superior animals are being identified and merchandized. Correlation studies were carried out to determine which traits contributed to, or which were more highly correlated, with price. In addition, a stepwise regression procedure was used to evaluate the relative importance of the various variables contributing to price.

Results and Discussion

Differences in mean values for animals eligible for sale compared with those not eligible for sale are shown in Table 2. Sale-eligible animals were consistently higher, or more desirable, than non-sale animals in final weight, total and body weight gain, and all measures of fleece weight. These differences were not statistically significant for body weight, but were significantly different for all measures of weight gain and fleece weight except for grease fleece weight in 1991. Fleece yield and lock length were significantly higher for 3 of the 4 years. Sale-eligible animals were consistently finer and had lower levels of kemp and med fibers than non-eligible animals. The only exception to this statement was for percentage of kemp in 1991, in which the values were essentially the same (i.e., .01 difference). These differences tended to be statistically significant in 1990 and 1991, whereas only some values were significant in 1988-89.

Table 2. Differences in average values for sale-eligible and non-sale animals.

	1988	1989	1990	1991
Init. wt (lb)	-3.92	-.76	-2.68	-0.11
Final wt (lb)	3.96	5.21	3.27	4.55
ADG (total,lb)	.07*	.053*	.054*	.039*
ADG (body,lb)	.05*	.046*	.047*	.037*
Gr.fl.wt (lb)	2.96*	1.15*	1.07*	.43
Cl.fl.wt (lb)	2.06*	1.07*	.98*	.60*
Adj.cl.fl.wt (lb)	2.09*	1.10*	1.06*	.60*
Yield (%)	-.02	1.66*	1.35*	1.58*
Lock lgth. (in.)	.15*	.13	.19*	.19*
Neck diam. (µm)	-.47	-1.91*	-1.92*	-2.11*
Side diam. (µm)	-.32	-.94	-1.93*	-2.00*
Br. diam. (µm)	-.38	-1.52	-2.30*	-3.06*
Avg. diam. (µm)	-.39	-1.45	-2.04*	-2.39*
Med fiber (%)	2.68	-.66	-1.40*	-1.22*
Kemp fiber (%)	-.20*	-.06	-.09*	.01
Face cov. score	.05	.09	.02	.20
Neck cov. score	.22	.08	.00	.17*
Character score	.47*	.39*	.28*	.35*
Kemp score	-.24*	.02	-.16*	-.11*
Index value	13.77*	10.05*	10.39*	8.69*
Index ratio	31.3*	33.38*	38.29	25.98*
Testes circ. (cm)	.37	.44*	.40*	.03

* Statistically significant at the 0.05 level of probability.
** Statistically significant at the 0.01 level of probability.

It may be worthwhile to note that the coefficient discriminating against fiber diameter was higher in the last 3 years than in the first. Face cover scores did not differ significantly between the sale-eligible and non-eligible animals, and such differences that did exist were positive (in the wrong direction). This is possibly explained by a positive correlation between face cover score and fleece weight under confined conditions where blindness is not a factor, and to the fact that no advantage was given in the index for values below 2 (1 in 1991). There is a positive difference for neck cover score favoring the sale animals, but this was significant only in 1991. There was a consistent and significant difference in favor of the sale-eligible animals in respect to character score and index value or index ratio. The latter is automatic because the animals were sorted on index.

The above data evaluate the selection procedure but do not provide information on how the producers or purchasers may view the relative importance of the various traits. Shown in Table 3 are the correlations of the various traits with price received at auction for the animals actually sold. These data are provided for the same 4 years, as well as an average for the 4 years and a pooled value for the 4 years. It is not possible to provide a statistical evaluation of the average values. In addition, a correlation value for index ratio and price is reported for pooled values only. Within a given year, the correlations involving index value and index ratio are the same. However, when these are pooled across years, they are not the same, and the index ratio is a much more valuable statistic because with the index ratio, year-to-year variations tend to be removed.

Among the variables listed, index value (or index ratio) is most closely related to price. This indicates that producers tend to be influenced by index, but there is perhaps some degree of bias to this in that sale order is determined by the index. The correlations between individual performance traits and price tend to be lower than many might have expected. However, this should be expected with the large number of traits involved. It is simply not possible to select for or to emphasize a large number of traits at the same time.

There is a reasonable degree of consistency, indicating that prices are influenced by size or gains. Various measures of fleece weight and fiber diameter present a different picture. Although the values are for the most part positive, there is a significant relationship between fleece weight and price in 1990 and 1991 only. In the case of fiber diameter, the correlations are for the most part negative (as expected), but these are significant only in 1988 and 1989. The highest relationship is in 1989, the year in which sale prices were highest. It seems apparent that in 1989, purchasers were searching for fine-haired goats but have relaxed this tendency in 1990 and

Table 3. Correlation of sale price and various performance traits.

	1988	1989	1990	1991	Avg.	Pooled
Final weight	.133	.218	.284*	.474**	.365	.284**
Total gain	.284*	.273*	.268*	.159	.246	.221**
Body wt gain	.265*	.274*	.229	.129	.224	.211**
Gr. fleece wt	.046	-.074	.249*	.219	.110	-.001
Clean fl. wt	.132	.047	.398**	.261*	.210	.115
Adj. cl. fl. wt	.134	.022	.394**	.105	.164	.068
Yield	.112	.269	.174	.094	.162	.204**
Lock length	-.129	.084	.175	-.007	.030	.139*
Neck diameter	-.264*	-.353**	-.048	-.027	-.172	-.230**
Side diameter	-.224	-.427**	.064	-.055	-.161	-.198**
Britch diameter	-.066	-.355**	-.015	.012	-.111	-.102
Average diameter	-.204	-.443**	-.001	-.096	-.186	-.197**
Med (%)	.007	-.258*	-.012	-.201	-.116	-.096
Kemp (%)	-.080	-.048	-.019	-.407**	-.139	-.133*
Face cover	.032	.045	.061	.121	.065	.066
Neck cover	.047	.155	-.067	.141	.069	.092
Kemp score	-.007	-.146	.012	-.169	-.078	-.093
Character	.119	.282*	.227	.311*	.235	.292**
Index	.555**	.747**	.672**	.579**	.638	.215**
Index ratio	.555*	.747**	.672**	.579**	.638	.589**

* Statistically significant at the 0.05 level of probability.
** Statistically significant at the 0.01 level of probability.

1991. There appears to be a good explanation for this in mohair price trends. The correlations involving med and kemp tend to be negative (as expected), but of low or non-significant magnitude except in one year (1990). However, it should be remembered that truly kempy animals were sifted from the sale group.

No significant relationship exists between face cover and price. There appears to be a consistent relationship between character or character score and price, indicating that producers are influenced either by the character score or by their own evaluation of this trait. It also may be possible that character is contributing to price through its relationship to other traits.

Another approach to evaluating the traits that contribute to price is stepwise regression analysis. The results of this analysis are shown in Table 4. The analysis was continued through eight variables. Above this number, variables (traits) were picked up that did not make a statistically significant contribution of price. These analyses strongly indicate that index was most important, followed by fleece character. Following this, some measure of weight or size was third. Other variables in order of their appearance in the model were neck or average diameter, neck score, lock length, adjusted clean fleece weight, and kemp percentage.

This analysis also confirms that prices are greatly influenced by index and character, and weight and diameter have secondary status. Other variables are correlated with price, but at a lower magnitude.

Table 4. Results of stepwise regression analysis of variables contributing to sale price.

No. variables included in model	Variables included	R^2 (R^2 x 100 = % variation in price accounted for by model)
1	Index	.347
2	Index character	.399
3	Index character initial weight	.455
4	Index character initial weight neck diameter	.482
5	Index character final weight neck diameter neck score	.485
6	Index character final weight neck diameter neck score lock length	.531
7	Index character final weight adj. clean fleece wt average diameter lock length kemp percent	.544
8	Index character final weight adj. clean fleece wt average diameter lock length kemp percent neck score	.552

There are two ways in which a variable may contribute to price. These are through their influence on the index or by purchasers placing selective emphasis on individual traits of greater interest to them. There are also two ways the testing program, or test organizers, may be influenced by this information. One of these is to continue to use an index to attempt to influence or place appropriate emphasis on the various traits considered to be important or to change the index to attempt to conform with apparent producer interest. In view of the variability in the price trends and correlations in only these 4 years, it appears that index changes should be minimized and that the data be presented in a manner permitting producers to follow their own interests.