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Growth and Carcass Characteristics of Conventionally Raised Lambs Versus Naturally Raised Lambs[1]

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Summary

This study compared growth and carcass quality of conventionally and naturally raised lambs. The hypothesis tested was conventionally raised lambs would have increased growth, but conventional management would not affect carcass characteristics. Two hundred eighty-eight Rambouillet x blackface (Suffolk and Hampshire) lambs (34.1 kg ± 0.13 kg) were randomly assigned to conventional (CONV) or naturally raised (NAT) treatments (6 pens/treatment; 24 lambs/pen) and fed ad libitum via self feeders for 112 d. The NAT lamb diet was 80 percent corn and 20 percent commercial supplement (DM basis; 87.9 percent TDN and 15.8 percent CP) with decoquinate. The NAT lambs were not given antibiotics or growth promoting implants. Conventionally raised lambs were fed a similar diet, with decoquinate, chlortetracycline, and lasalocid included, and were implanted with 36 mg zeranol on d 28. Lambs were weighed and feed refusals collected every 28 d. Lambs were harvested and carcass data collected 24 h post chill. Overall, CONV lambs had increased ADG (0.35 kg vs 0.33 kg ± 0.006 kg; $P = 0.03$) and final BW (73.3 kg vs. 71.3 kg ± 0.71 kg; $P = 0.07$) compared to NAT lambs, but DMI (1.64 kg/d vs 1.58 kg/d ± 0.04 kg/d; $P = 0.55$) and G:F (0.22 vs 0.21 ± 0.004; $P = 0.32$) were not different between treatments. Naturally raised lambs had greater rib eye area ($P = 0.03$), decreased body wall thickness ($P = 0.05$), and increased percentage boneless, closely trimmed retail cuts ($P = 0.05$). More CONV lambs prolapsed (8.3 percent vs 0 percent; $P = 0.001$) which increased mortality (2.8 percent vs 0 percent; $P = 0.01$). In the current trial, naturally raised lambs had decreased growth, marginal increases in carcass quality, and were less susceptible to prolapse and mortality than conventionally raised lambs.

Key Words: Antibiotic, Carcass Traits, Feedlot Performance, Lamb, Naturally Raised, Zeranol

Introduction

Consumer demand for natural food products has caused substantial increases in natural food sales (Davis and Stewart, 2002). However, there is a large disconnect between consumer perception of natural meat production and actual management practices of natural producers. Until recently, federal regulations have not addressed this disconnect. In January, 2009, the USDA released the Naturally Raised Marketing Claim, which provides voluntary guidelines for production of naturally raised products. According to the standards, naturally raised animals should be raised "…without growth promotants and antibiotics and that have never been fed mammalian or avian by-products…" (Agricultural Marketing Service, 2009). Adhering to, and marketing under the Naturally Raised Marketing Claim, affords producers the opportunity to offer a lamb product as raised "natural".

Growth promotants and antibiotics offer a considerable performance advantage in conventional-management systems. Administration of antibiotics, such as chlortetracycline (Bridges et al., 1953; Johnson et al., 1956; Kunkel et al., 1956), the ionophore lasalocid (Schwulst et al., 1991), and zeranol (Hufstedler et al., 1996; Hutcheson et al., 1992; Salisbury et al., 2007), improve growth in lambs. Numerous studies report improved growth and carcass characteristics in conventionally raised cattle compared to naturally raised cattle (Sawyer et al., 2003; Thompson et al., 2010). The advantages in growth and carcass characteristics in conventional-production systems suggest natural-meat products need a premium for natural-production systems to be economically viable. The objective of the present study was to determine the effects of naturally raised and conventional-management practices on growth and carcass quality in finishing lambs.

Materials and Methods

Animals and Treatments

All experimental protocols were approved by the North Dakota State University Animal Care and Use Committee. Tails were docked, males castrated, and all lambs vaccinated for *Clostridium perfringens* types C and D and tetanus (CD-T; Bar Vac CD-T, Boehringer Ingelhein, Ridgefield, Conn.) at two wks of age. Lambs were weaned and vaccinated with CD-T again at 60 d of age and d -1 (4 mo of age) of the trial. Two hundred eighty-eight, spring-born, Rambouillet x blackface (Suffolk and Hampshire) wether and ewe lambs (BW ± SD; 34.0 kg ± 0.13 kg) were stratified by BW, sex, and breed and randomly assigned to 12 outdoor feedlot pens (24 lambs/pen) on May 20, 2009. Pens were randomly assigned to treatment, conventionally raised (CONV) or naturally raised (NAT), with pen serving as the experimental unit. Treatments were applied in a completely randomized design to evaluate lamb growth and carcass characteristics under conventional- and natural-management practices.

Lambs were adapted to a concentrate diet from a creep pellet following weaning. Treatment diets were balanced to meet or exceed CP and energy (NE) requirements (NRC, 2007). The dietary treatments were formulated to have a minimum Ca to P ratio of 2:1. Conventional lambs were raised using best-management practices, including supplementation with lasalocid (0.15 g lasalocid/kg CONV market lamb pellet; 90 percent DM basis), decoquinate (1.25 g/kg; Dekade Krumbles; 90 percent DM basis, CHS Nutrition, Sioux Falls, S.D.), and chlortetracycline (CTC; 8.82 g/kg; CTC 4G; 90 percent DM basis, CHS Nutrition, Sioux Falls, S.D.), and implantation with zeranol (Ralgro, Schering-Plough Animal Health Corp., Union, N.J.). The CONV diet was 78.6 percent whole, shelled corn, 19.8 percent medicated, market-lamb pellet (Market Lamb 38-10 Supplement, CHS Nutrition, Sioux Falls, S.D.), 1.2 percent supplement containing decoquinate, and 0.4 percent supplement containing CTC

Table 1. Ingredient and nutritional composition of diets fed to feedlot lambs

	Diets[1]	
Item	CONV	NAT
Ingredient, %	DM basis	
Whole Corn	78.6	80.0
CONV Market Lamb Pellet[2]	19.8	-
NAT Market Lamb Pellet[3]	-	20.0
Decoquinate[4]	1.2	-
Chlortetracycline[5]	0.4	-
Nutrient concentration		
CP, %	15.7	15.8
TDN, %	87.5	87.9
NEm, Mcal/kg[6]	2.12	2.13
NEg, Mcal/kg[7]	1.36	1.39
Crude Fat, %	3.80	3.83
ADF, %	3.63	3.13
Ash, %	4.59	4.43
Ca, %	1.11	0.95
P, %	0.40	0.40

[1] Treatments: CONV (conventional) and NAT (naturally raised).
[2] Conventional Market Lamb Pellet contained: 0.15 g/kg lasalocid, 38% CP, 4.25% Ca, 0.6% P, 3.5% salt, 1.2 mg/kg Se, 52.920 IU/kg Vitamin A, 5.292 IU/kg Vitamin D, and 154 IU/kg Vitamin E (90% DM basis).
[3] Naturally raised Market Lamb Pellet contained: 0.1432 g/kg decoquinate, 38% CP, 4.25% Ca, 0.6% P, 3.5% salt, 1.2 mg/kg Se, 52,920 IU/kg Vitamin A, 5,292 IU/kg Vitamin D, and 154 IU/kg Vitamin E.
[4] Dekade Krumbles contained 1.25 g/kg decoquinate (90% DM basis).
[5] CTC 4G contained 8.8 g/kg chlortetracycline (90% DM basis).
[6] Net energy for maintenance; calculated analysis.
[7] Net energy for gain; calculated analysis.

(DM basis; Table 1). Conventional lambs (as defined in this study) were implanted in the ear with three, 12 mg zeranol pellets on d 28. Conventional lambs were treated with antibiotics as necessary and remained in the study (12 lambs treated for prolapse, 1 lamb treated for cystic infection). The NAT diet was 80 percent whole, shelled corn and 20 percent non-medicated, commercial pellet (Market Lamb 38-10 Supplement, CHS Nutrition, Sioux Falls, S.D.; DM basis; Table 1); the NAT commercial pellet contained decoquinate (0.1432 g decoquinate/kg NAT pellet, 90 percent DM basis). Naturally raised lambs did not receive antibiotics in any form (feed, water, injectable, etc). If treatment with antibiotic administration was necessary, the treated lamb was removed from the pen as well as the data set. Lambs were offered feed ad libitum via bulk feeders as mixed diets for both treatments. Lambs had continuous access to fresh water and shade. Water tanks were cleaned weekly, or more often as needed. Lamb health was monitored daily, with morbid lambs monitored two to three times daily.

Experimental Periods and Sampling Procedures

The study was initiated in May and concluded in August of 2009. Lambs were weighed two consecutive days at initiation (d -1 and d 0) and termination (d 111 and d 112) of the trial to determine initial and final BW. Additionally, lambs were weighed once every 28 d throughout the study. Feed refusals were collected every 28 d to determine period DMI and G:F. Feed-ingredient-grab samples (approximately 0.2 kg) were collected once every 28 d, dried at 55°C for 48 h to determine DM, and analyzed by a commercial laboratory (Midwest Laboratories, Omaha, Neb.) for CP, calculated energy, crude fat, ADF, and mineral concentrations. Two-hundred forty-five lambs (126 CONV and 119 NAT), weighing a minimum of 61 kg were transported (768 km) to Iowa Lamb Corp. (Hawarden, Iowa) and harvested on d 116. Data from lambs too light for shipment to commercial abattoir (15 CONV, 24 NAT) were included in growth analyses, but not carcass analyses. One lamb was treated and removed from the study due to complications not related to treatment. Four mortalities occurred over the course of the study. Dry matter intake for pens in which lambs died or were removed from the study was accounted for using a weighted average of lambs per pen for that period. Lambs were removed from the data set for periods in which they were not present when calculating ADG, DMI, and G:F.

Carcass data were collected 24 h post chill by trained university personnel. Data collected included HCW, leg score, conformation score, fat depth (over the 12th rib), body wall thickness (at the 12th rib), ribeye area, flank streaking, quality grade, and yield grade. Leg score, conformation score, and quality grade were scored on a scale of 1 to 15 (1 = cull; 15 = high prime). Flank streaking was assigned, with scores of 100 to 199 = Practically Devoid, 200 to 299 = Traces, 300 to 399 = slight, 400 to 499 = Small, and 500 to 599 = Modest. Percentage of boneless, closely trimmed retail cuts (%BCTRC) was calculated using the equation from Savell and Smith (2000).

Statistical Analysis

Lamb performance data were analyzed as a completely randomized design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, N.C.) with pen serving as experimental unit. Carcass data were analyzed similarly, with missing data points from underweight lambs not included in the data set. Repeated measures was used to analyze period effects for body weight, ADG, DMI, and G:F. The model specifications included treatment, period, and treatment x period interaction. The covariance structure used was 1st Order Ante-dependence for body weight, DMI, and G:F. Simple covariance structure was used for ADG. Other structures were tested; however, 1st Order Ante-dependence and Simple were the best fit, respectively. Results are presented as least squares means with differences considered significant at $P \leq 0.10$.

Results and Discussion

Growth

Results for lamb growth are reported in Table 2. Overall, CONV lambs had increased ADG (0.35 kg vs 0.33 kg ± 0.006 kg; $P = 0.03$) and d 112 BW (73.3 kg vs 71.3 kg ± 0.71 kg; $P = 0.07$) compared to NAT lambs, but DMI (1.64 kg/d vs 1.58 kg/d ± 0.04 kg/d; $P = 0.55$) and G:F (0.22 kg gain/kg feed vs 0.21 kg gain/kg feed ± 0.004 kg gain/kg feed DMI; $P = 0.32$) were not different between treatments (d 0 to d 112; $P \geq 0.32$). Treatment x period effects were observed ($P \leq 0.003$) for ADG, BW, DMI, and G:F. Body weight was greater in CONV lambs on d 56 (57.0 kg vs 54.7 kg ± 0.53 kg; $P = 0.02$) d 84 (66.0 kg vs 62.9 kg ± 0.56 kg; $P = 0.005$), and d 112 (73.3 kg vs 71.3 kg ± 0.71 kg; $P = 0.07$). Conventional lambs gained faster (0.47 kg vs 0.39 kg ± 0.01 kg; $P < 0.001$), consumed more daily DM (1.68 kg vs 1.57 kg ± 0.02 kg; $P = 0.001$), and gained more efficiently (0.28 kg gain/kg feed vs 0.24 kg gain/kg feed ± 0.007 kg gain/kg feed DMI; $P = 0.005$) than NAT lambs from d 29 to d 56. However, NAT lambs gained more (0.30 kg vs. 0.26 kg ± 0.01 kg; $P = 0.09$) and were more efficient from d 85 to d 112 (0.18 kg gain/kg feed vs 0.15 kg gain/kg feed ± 0.008 kg gain/kg feed DMI; $P = 0.02$) than CONV lambs, respectively.

In other reports in the literature, lasalocid increased ADG and G:F for lambs (Funk et al., 1986; Schwulst et al. 1991). Fluharty et al. (1999) reported increased DMI and decreased days on feed for lambs fed concentrate diets and supplemented with lasalocid, but reported no differences in G:F, ADG, or final weight. The Fluharty data is in contrast to research that found decreased DMI for cattle fed lasalocid in high-concentrate diets (Berger et al., 1981), or low-concentrate diets (Bartley et al., 1979), and no difference in DMI for lambs supplemented with lasalocid in high-concentrate diets (Paterson et al., 1983). Research by Paterson et al. (1983) is in agreement with the results of the present study. Moreover, research in cattle has indicated the addition of lasalocid to high-concentrate rations increased ADG and G:F (Berger et al., 1981; Thonney et al., 1981). These results agree with the present study findings of increased overall ADG and increased G:f for d 29 to d 56, but not with the decreased G:F from d 85 to d 112.

The effects of CTC on feedlot lambs have been inconsistent, but research has indicated that CTC can improve ADG (Hatfield et al., 1954; Johnson et al., 1956) and feed efficiency (Hatfield et al, 1954; Kunkel et al., 1956). This agrees

Table 2. Comparison of conventional and natural management practices on feedlot lamb performance, incidence of prolapse, and mortality

Item	Treatment[1]			
	CONV	NAT	SEM[2]	*P*-value[3]
Wt[4], kg				
d 0	34.1	34.1	0.13	0.97
d 28	43.9	43.6	0.42	0.96
d 56	57.0	54.7	0.53	0.02
d 84	66.0	62.9	0.56	0.005
d 112	73.3	71.3	0.71	0.07
ADG[5], kg				
d 0-28	0.35	0.36	0.01	0.95
d 29-56	0.47	0.39	0.01	<0.001
d 57-84	0.32	0.30	0.01	0.13
d 85-112	0.26	0.30	0.01	0.09
d 0-112	0.35	0.33	0.006	0.03
Intake[6], kg DM · hd^{-1} · d^{-1}				
d 0-28	1.39	1.47	0.05	0.26
d 29-56	1.68	1.57	0.02	0.001
d 57-84	1.75	1.67	0.03	0.87
d 85-112	1.77	1.64	0.04	0.33
d 0-112	1.64	1.58	0.04	0.55
G:F[7]				
d 0-28	0.26	0.25	0.01	0.45
d 29-56	0.28	0.24	0.007	0.005
d 57-84	0.18	0.18	0.004	0.24
d 85-112	0.15	0.18	0.008	0.02
d 0-112	0.22	0.21	0.004	0.32
Prolapse, %	8.3	0	1.0	0.001
Mortality, %	2.8	0	0.6	0.01

[1] Treatments: CONV (conventionally raised) and NAT (naturally raised).
[2] Standard Error of Mean; n = 6.
[3] P-value for F-tests of mean.
[4] P-values for period body weight treatment ($P = 0.04$), period ($P < 0.001$), treatment x period ($P = 0.003$).
[5] P-values for ADG treatment ($P = 0.03$), period ($P < 0.001$), treatment x period ($P < 0.001$).
[6] P-values for Intake treatment ($P = 0.55$), period ($P < 0.001$), treatment x period ($P = 0.003$).
[7] P-values for G:F treatment ($P = 0.32$), period ($P < 0.001$), treatment x period ($P < 0.001$).

with the present study, which found increased ADG and period G:F for CONV lambs compared with NAT lambs, and no difference for DMI between treatments.

The implanting strategy in the present study is divergent from that traditionally utilized in feedlot lambs. Historically, the lamb-feeding industry used 12 mg zeranol implants. However, there is not a 12 mg zeranol implant currently available; therefore, lambs in the present study were implanted with a commercially available 36 mg zeranol implant (three, 12 mg zeranol pellets). The majority of previous research in lambs utilized single or multiple implants containing a total of 12 mg of zeranol. Results from d 29 to d 56 in the present study agree with previous research that indicates lambs implanted with 12 mg zeranol have increased ADG and G:F when implanted with 12 mg zeranol one, two, three, or five times (Hutcheson et al., 1992; Hufstedler et al., 1996; Salisbury et al., 2007) compared with non-implanted lambs. However, zeranol can also decrease DMI in lambs implanted with 12 mg zeranol twice (Hutcheson et al., 1992), in contrast with the results of the present study. The increased overall ADG of the present study (d 0 to d 112) also agrees with the aforementioned research. The combination of decreased ADG and non-significant increase in DMI from d 85 to d 112 in CONV lambs resulted in CONV lambs having decreased G:F from d 85 to d 112 compared to NAT lambs. The increased G:F from d 29 to d 56 combined with the decreased G:F from d 85 to d 112 resulted in no differences between treatments for G:F from d 0 to d 112. Similar to Salisbury et al. (2007), the present study found no differences between conventional and natural treatments for DMI from d 0 to d 112.

A limited amount of research is present in the literature comparing growth of livestock in natural- and conventional-management systems. Current research indicates conventionally raised livestock have a distinct advantage compared to naturally raised livestock. Faulkner et al. (2010) compared steers managed in conventional- and natural-management systems. Steers under conventional management were fed monensin and tylosin, and were implanted with growth promotants. Naturally raised steers received no antibiotics or implants. Conventional steers had increased final body weight, ADG, and G:F, as well as decreased days on feed and DMI. Thompson et al. (2010) also observed increased BW, ADG, and G:F in cattle fed monensin and implanted with a zeranol implant and a progesterone and estradiol benzoate implant compared to cattle raised without growth promotants. Research analyzing the effects of implants and antibiotic-feed additives found implants improved growth, but feed additives had no effect on growth (Sawyer et al., 2003). The improved performance of implanted steers agrees with other research (Guiroy et al., 2002; Johnson et al., 1996; Pampusch et al., 2003).

On d 84, CONV and NAT body weights were 66.0 kg and 62.9 kg, respectively; heavy enough for harvest (average U.S. lamb harvest weight is 61.2 kg; Viator et al., 2007); however, ending the trial on d 84 was not feasible due to the logistics of transporting animals to the harvest facility. Naturally

Table 3. Comparison of conventional and natural management practices on feedlot lamb carcass characteristics

	Treatment[1]			
Item	**CONV**	**NAT**	**SEM[2]**	***P*-value[3]**
HCW, kg	37.0	36.5	0.36	0.35
Leg Score[4]	11.5	11.5	0.07	0.95
Conformation Score[4]	11.5	11.6	0.06	0.50
Fat Depth, cm[5]	0.84	0.79	0.03	0.25
Body Wall Thick, cm	2.82	2.69	0.03	0.05
Ribeye Area, cm^2	16.58	17.16	0.13	0.03
Flank Streaking[6]	351.03	356.89	5.85	0.50
Quality Grade[4]	11.4	11.4	0.06	0.85
Yield Grade[7]	3.72	3.55	0.1	0.25
BCTRC, %[8]	43.57	43.92	0.11	0.05
Lean, kg	16.1	16.0	0.13	0.69
Dressing, %	49.26	49.26	0.15	0.99

[1] Treatments: CONV (conventionally raised) and NAT (naturally raised).
[2] Standard Error of Mean; n = 6.
[3] *P*-value for F-tests of mean.
[4] Leg score, conformation score, and quality grade: 1 = cull to 15 = high prime.
[5] Adjusted fat depth and yield grades.
[6] Flank streaking: 100-199 = practically devoid; 200-299 = traces; 300-399 = slight; 400-499 = small; 500-599 = modest.
[7] Yield Grade = 0.4 + (10 x adjusted fat depth, in).
[8] Boneless closely trimmed retail cuts, % = (49.936 – (0.0848 x 2.205 x HCW, kg) - (4.376 x 0.3937 x fat depth, cm) – (3.53 x 0.3937 x body wall thickness, cm) + (2.456 x 0.155 x ribeye area, cm^2)).

raised lambs had improved G:F and ADG from d 85 to d 112 compared to CONV lambs. Had the trial ended on d 84, CONV lambs may have had increased overall G:F in addition to increases in weight gain.

Prolapse and Mortality

The increased incidence of vaginal and rectal prolapses ($P = 0.001$) in the CONV treatment raises concerns about animal health (Table 2). The increased incidences of prolapses subsequently led to increased percent mortality ($P = 0.01$) in CONV lambs. Incidence of prolapse has been cited as a reason for decreased use of zeranol by lamb feeders (Lupton, 2008). Treatment for prolapse included antibiotics and purse-string sutures to keep expelled tissue in place. In this study, 12 CONV lambs prolapsed, 5 CONV lambs prolapsed repeatedly (4, 2, 2, 2, and 3 times, respectively), and 4 CONV lambs died as a result of complications from prolapses. Salisbury et al. (2007) reported a numerical increase in percent prolapse in feeder lambs implanted once or twice with 12 mg zeranol, but did not report increased mortality associated with the increased prolapse. Arnsperger et al. (1976) also found increased prolapses in lambs implanted with zeranol and raised in the feedlot, but could not find any differences between implanted and non-implanted lambs raised on pasture. Anecdotal evidence also indicates as many as 50 percent of feedlot lambs in Mexico are implanted with zeranol, yet these lambs do not experience an increased incidence of prolapse. The absence of prolapse in Mexican lambs implanted with zeranol could be associated with the use of higher-forage diets in Mexican feedlot rations compared to counterparts in the United States (Amaya, 2010). No other factors associated with the present study have been implicated in increased percent prolapse in lambs.

Carcass Characteristics

The effects of lamb management (CONV vs NAT), as described in this paper, on subsequent carcass characteristics are given in Table 3. Naturally raised lambs had decreased body wall thickness, increased ribeye area (REA), and increased percent boneless, closely trimmed, retail cuts (%BCTRC; $P \leq 0.05$) compared to CONV lambs (Table 3). Other carcass measurements were similar between treatments ($P \geq 0.25$). The decreased %BCTRC in CONV is a result of the decreased REA and increased body wall thickness. The results of the present study disagree with previous research comparing the effects of natural and conventional management on carcass characteristics of steers. Conventionally managed steers have been reported to have increased HCW and REA and decreased marbling score when compared to naturally managed steers (Faulkner et al., 2010; Thompson et al., 2010). Additionally, conventionally managed steers had increased dressing percent and decreased KPH and yield grade compared to naturally managed steers (Faulkner et al., 2010). The effects of zeranol on carcass characteristics are inconsistent. Zeranol has been reported to increase fat depth (Field et al., 1993), increase leg score (Hutcheson et al., 1992; Nold et al., 1992), decrease kidney and pelvic fat (Hufstedler et al., 1996), and increase carcass weight (Hutcheson et al., 1992; Wilson et al., 1972). Lasalocid has not been reported to influence carcass characteristics in sheep (Fluharty et al., 1999) or cattle (Berger et al., 1981). Chlortetracycline does not alter carcass quality, but may improve quality grade of carcasses (Hatfield et al., 1954; Jordan et al., 1956). Differences in quality grade were not observed in the present study ($P = 0.85$).

Economics

A simple, enterprise budget is presented in Table 4 to compare the costs and profits associated with raising ten lambs according to the respective treatments. The revenue from lambs sold was calculated according to final BW for each treatment, with corrections made for percent mortality. Factors included in costs for lamb production were: lamb-purchase price, feed cost, additional labor cost from prolapse, implant cost, and yardage. Total costs were increased for CONV lambs due to increased costs

Table 4. Cost of raising a pen of ten lambs using conventional or natural management systems

Item	Unit	CONV[1] Price ($)	CONV Quantity	CONV Amount ($)	NAT Price ($)	NAT Quantity	NAT Amount ($)
Revenue							
Lamb Harvested[2]	Kg	2.03	712	1445.36	2.03	713	1447.39
Total Revenue				**1445.36**			**1447.39**
Costs							
Lamb[3]	Kg	2.76	341	941.16	2.76	341	941.16
Feed[4]	Kg	0.218	2060	449.86	0.217	1980	430.29
Labor (Prolapse)[5]	Prolapse	7.2	0.83	5.98	7.2	0	0
Implant	Dosage	1.25	10	12.50	1.25	0	0
Yardage[6]	Head/Day	0.04	1120	44.80	0.04	1120	44.80
Total Costs				**1454.30**			**1416.25**
Profit				**(8.94)**			**31.14**

[1] Treatments: CONV (conventionally raised) and NAT (naturally raised).
[2] Market price determined by sale prices at Hawarden Lamb Corporation, Hawarden, IA at time of sale. Conventional lamb harvested accounts for 2.8% mortality.
[3] Purchase price estimated based on USDA National Weekly Market Summary at time of purchase.
[4] Rations calculated using feed costs of $0.15/kg corn, $0.45/kg CONV pellet, $0.48/kg NAT pellet, $0.73/kg Deccox, and $0.73/kg CTC. DMI is 1.64 and 1.58 kg/hd/d for CONV and NAT lambs respectively, fed for 112 d.
[5] Labor cost for prolapse calculated based on 0.5 hr of work at $12/hr, plus 12 mL oxytetracycline ($0.10/mL).
[6] Yardage rate was based on commercial rates and accounted for fixed costs of infrastructure, mixer wagon and tractor, and labor for feeding and daily health checks.

for labor to treat prolapses, implants, and feed. Additionally, CONV lambs had decreased revenue resulting from increased mortality. Therefore, NAT lambs were more economically viable despite having decreased growth compared to CONV lambs.

Conclusions

Lambs raised using conventional-management system had increased ADG and final BW compared with naturally raised lambs, but there were no differences in DMI or G:F. Additionally, conventionally raised lambs had an increased incidence of prolapse and mortality. Although the majority of carcass characteristics were not different between treatments, lambs from naturally raised management did have increased ribeye area and decreased body wall thickness, subsequently increasing % BCTRC. Future research should evaluate if improved carcass characteristics can again be attained from naturally raised management. Research should also examine whether these conventional-management practices can be used to increased growth without increasing incidence of prolapse and mortality.

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Effects of Rumen-Protected Arginine Supplementation on Ewe Serum-Amino-Acid Concentration, Circulating Progesterone, and Ovarian Blood Flow[1]

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Summary

The objectives of this research were to determine if rumen-protected arginine supplemented to ewes on d 8 to d 13 of the estrous cycle affected serum-amino-acid concentration, ovarian blood flow, and circulating progesterone. Nineteen multiparous Dorset ewes (63.8 kg ± 1.1 kg initial BW) were individually housed and randomly allocated to one of four rumen-protected arginine treatments: 0 (CON; n = 5), 90 mg/kg BW supplemental arginine (90 ARG; n = 4), 180 mg/kg BW supplemental arginine (180 ARG; n = 5), or 360 mg/kg BW supplemental arginine (360 ARG; n = 5). Following estrous synchronization, ewes were individually fed rumen-protected arginine blended into 150 g ground corn, which was immediately followed with 650 g of a pelleted diet (2.40 Mcal ME/kg and 12.9 percent CP; DM basis) on d 8 to d 12 of the estrous cycle. Ewes fed 360 ARG generally had greater serum- arginine concentrations than CON, 90 ARG, and 180 ARG on d 11 ($P \leq 0.07$) and d 12 ($P \leq 0.03$). On d 11, arginine as a percent of total amino acid concentration was greater in 360 ARG compared with CON and 90 ARG ($P \leq 0.05$). Total essential amino-acid concentration was elevated in 360 ARG compared with 90 ARG and 180 ARG ($P \leq 0.03$) on d 12. Arginine supplementation increased peak systolic velocity in the corpus luteum (CL) for 360 ARG and 90 ARG compared to CON ($P \leq 0.04$). Flow time (milliseconds) in the ovarian hilus was increased and CL was generally increased in 360 ARG compared to all other treatments ($P \leq 0.04$ and $P \leq 0.09$, respectively). Supplemental rumen-protected arginine had no effect on serum concentration of progesterone ($P > 0.50$). Results indicate that rumen-protected arginine supplemented to ewes at the rate of 360 mg/kg BW may increase circulating serum arginine concentration, in addition to increasing ovarian blood flow.

Key Words: Arginine, Ovarian Hemodynamics, Sheep

Introduction

As a precursor for nitric oxide, polyamines, creatine, proteins, urea, and glutamate, the amino acid arginine plays a vital role in metabolism and reproduction (Wu and Morris, 1998). Nitric oxide is the endothelium-derived relaxing factor essential for increasing systemic vasodilation (Ignarro et al., 2001; Martin et al., 2001). Supplemental arginine has been reported to increase the number of live pigs born per sow (Mateo et al., 2007). Furthermore, pregnant rats supplemented with arginine throughout gestation exhibited an increase in embryonic survival and litter size (Zeng et al., 2008). Recent research by Luther et al. (2008) indicated that ewes injected with L-arginine during the first 15 d post-breeding had increased ovarian blood flow, serum progesterone, and fetal number, despite similarities in ovulation rates to control ewes. Collectively, these studies provide evidence that reproductive efficiency can be enhanced via supplementation of supranutritional levels of arginine.

In previous studies, arginine supplementation has been investigated only within monogastric species due to the catabolic fate of arginine within the rumen. To protect arginine from ruminal degradation, the amino acid must be encapsulated in a ruminal-protected product to partially escape the rumen, followed by being catabolized in the small intestine for absorption. Due to the lack of available rumen-protected arginine, research in ruminants has been limited. We hypothesize that feeding rumen-protected arginine will increase circulating levels of arginine in addition to increasing systemic blood flow through its role in nitric oxide synthesis. Our specific objectives were to determine the effects of feeding rumen-protected arginine to ewes on serum amino acids, ovarian hemodynamics, and serum progesterone.

Materials and Methods

Animals and Experimental Design

All animal procedures were approved by the North Dakota State University Institutional Animal Care and Use Committee.

Nineteen mature, multiparous Dorset ewes (63.8 kg ± 1.1 kg initial BW) were randomly allocated to one of four rumen-protected L-arginine treatments: 0 (CON; n = 5), 90 mg/kg BW supplemental arginine (90 ARG; n = 4), 180 mg/kg BW supplemental arginine (180 ARG; n = 5), or 360 mg/kg BW supplemental arginine (360 ARG; n = 5). Rumen-protected L-arginine (ARG 60; Eurhema Srl., Carviago, Itlay) was a 60 percent L-Arginine HCL product, calculated to have a minimum intestinal availability of 50 percent. Calculation of the dosage used assumed that 40 percent of arginine reaching the small intestine would be catabolized in this tissue (Wu and Morris, 1998), resulting in 30 percent of the consumed rumen-protected arginine reaching circulation. The 90 ARG treatment was estimated to deliver 27 mg L-arginine/kg BW to circulation, which was the injected dose used in previous studies (Luther et al., 2008).

For estrous synchronization, all ewes received a vaginally inserted, controlled-internal-drug release (CIDR-G®; 300 mg progesterone; Pharmacia & Upjohn Limited Co., Auckland, New Zealand) device for 12 d. Following CIDR removal, a single injection of 400 IU equine chorionic gondotropin (eCG®; Novormon 5000, Syntex S.A., Buenos Aires, Argentina) was given to initiate follicular development and ensure ovulation. After synchronization, ewes were moved into the Animal Nutrition and Physiology Center at NDSU (approximately 46.9° latitude and 96.8° longitude), where they were individually housed in 0.91-m x 1.2-m pens. The facility was temperature controlled (12°C to 21°C) and ventilated with lighting automatically timed to mimic daylight patterns.

Diet

Ewes were allowed a 7-d acclimation period to the facility and diet before beginning rumen-protected arginine supplementation on d 8 of the estrous cycle (d 0 = estrus). For 5 d, ewes were fed rumen-protected arginine blended into 150 g of ground corn, which was immediately followed with 650 g of a pelleted diet (44.9 percent beet pulp, 25.0 percent alfalfa meal, 19.7 percent soyhulls, 6.7 percent corn, 3.7 percent soybean meal; pelleted diet: 2.23 Mcal ME/kg and 13.6 percent CP, DM basis; total diet: 2.40 Mcal ME/kg and 12.9 percent CP, DM basis).

Ovarian Hemodynamics

On d 12 of the estrous cycle, color Doppler ultrasonography (Aloka SSD 3500, Tokyo, Japan) was used to determine ovarian hilus and luteal resistance index [(Peak systolic velocity – End diastolic velocity) / Peak systolic velocity], pulsatility index [(Peak systolic velocity – End diastolic velocity) / Time-averaged maximum velocity], peak systolic velocity, end diastolic velocity, mean velocity, and flow time in both ovaries.

Serum Analyses

Blood samples were collected via jugular venipuncture every 12 h from d 8 to d 13 of the estrous cycle. Serum was analyzed for progesterone concentration using a solid-phase, competitive, chemiluminescent enzyme immunoassay (Immulite 1000, Diagnostics Products Corp. Diagnostic Products Corp., Los Angeles, Calif.). All samples were analyzed as a single assay in duplicate form, with the intraassay CV 9.1 percent. Amino acid concentration (35 AA and metabolites) was determined using the HPLC MassTrak Amino Acid Analysis Solution developed by Waters Corporation (ACQUITY Ultra Performance LC, Waters Corporation, Milford, Mass.). Blood samples were refrigerated and allowed to coagulate for 2 h; thereafter, samples were centrifuged at 2,750 x g for 20 min at 4°C. Serum was removed and stored at -20°C for further amino acid and progesterone analyses.

Statistical Analysis

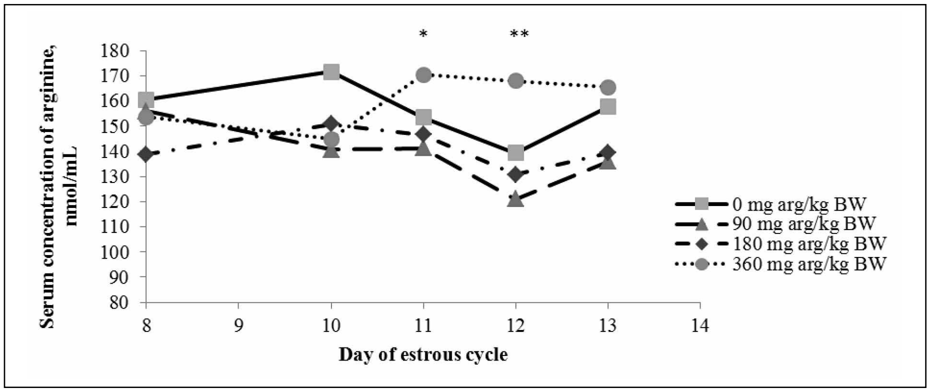
Ewe ovarian hemodynamic data were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) with arginine treatment as the fixed effect, pen serving as block, and animal serving as the experimental unit. Repeated measures was used to analyze day and treatment x day effects for serum data. The model specifications included treatment, day, and treatment x day interaction, with ewe serving as the random effect. The covariance structure used was 1st Order Antedependence. Simple covariance structure was used. Means were separated using LSD and were considered significant when $P \leq 0.10$.

Results

Serum Arginine Concentration

There was no effect of day or treatment x day for serum arginine concentration, total essential AA concentration, total AA concentration, arginine as a percent of total essential AA, or arginine as a % of total AA ($P \geq 0.14$). Ewes fed 360 ARG had greater serum arginine concentration than CON, 90 ARG, and 180 ARG on d 11 (175.5 nmol/mL vs. 153.2 nmol/mL, 132.3 nmol/mL, and 145.4 nmol/mL ± 8.6 nmol/mL, respectively; $P \leq 0.07$; Figure 1) and d 12 (166.4 nmol/mL vs. 142.7 nmol/mL, 121.7 nmol/mL, and 128.2 nmol/mL ± 7.4 nmol/mL, respectively; $P \leq 0.03$). On d 11, arginine as a percent of total amino acid concentration was greater in 360 ARG compared with CON and 90 ARG (7.16 nmol/mL vs. 6.19 nmol/mL, 5.70 nmol/mL ± 0.34 nmol/mL, respectively; $P \leq 0.05$; Table 1). Total essential amino acid concentration was elevated in 360 ARG compared with 90 ARG and 180 ARG ($P \leq 0.03$) on d 12. Supplemental rumen-protected arginine had no effect on citrulline or ornthine levels throughout the treatment period (data not reported; $P > 0.15$).

Figure 1. Effects of feeding graded amounts of rumen-protected L-arginine on serum arginine concentration (nmol/mL) in Dorset ewes (*$P = 0.01$; **$P = 0.002$) from d 8 to d 12 of the estrous cycle (SEM for arginine concentration = 4.54 nmol/ml; SEM for day of estrous cycle = 5.07 nmol/ml).



Ovarian Hemodynamics and Circulating Serum Progesterone

Arginine supplementation increased peak systolic velocity in the CL for 360 ARG and 90 ARG compared to CON (30.53 cm/s and 32.59 cm/s vs. 22.63 cm/s ± 2.48 cm/s, respectively; $P \leq 0.04$; Table 2). Flow time (milliseconds) in the ovarian hilus and corpus luteum was increased in 360 ARG compared to all other treatments ($P \leq 0.04$ and $P \leq 0.09$, respectively). Pulsatility index and resistance index did not differ among treatments for the CL and ovarian hilus ($P \geq 0.18$).

Supplemental, rumen-protected arginine had no effect on serum concentration of progesterone (CON, 6.17 ± 0.24; 90 ARG 6.14 ± 0.31; 180 ARG 5.93 ± 0.39 and 360 ARG 5.41 ± 0.44; $P \geq 0.50$).

Discussion

Arginine supplementation has primarily been evaluated in non-ruminant species. Limited research investigating arginine supplementation in ruminants has been conducted because of the high degree of ruminal arginine catabolism and lack of rumen-protected products. Research in pigs (Wu, 1997) and sheep (Luther et al., 2008) has indicated that intravenous injection of arginine at the rate of 27 mg of arginine/kg BW increased serum arginine within one hour of injection. Data published herein provides seminal information on the effects of rumen-protected arginine on serum arginine concentrations and ovarian hemodynamics in sheep. The 90 ARG treatment used in this study was estimated to deliver 27 mg arginine/kg BW to circulation over a 24 h period. This is in contrast to other studies (Wu, 1997; Luther et al., 2008), which used intravenously injected arginine. In the current study, only ewes supplemented with the largest dose (360 ARG) had greater serum-arginine concentrations, which occurred on d 11 and d 12 after 3 d and 4 d of supplementation, respectively.

Nitric oxide is produced when the enzyme nitric oxide synthase catalyzes the oxidation of L-arginine to L-citrulline and is considered the endothelium-derived relaxing factor essential for increasing systemic vasodilation (Ignarro et al., 2001; Martin et al., 2001; Gouge et al., 1998). Increased vascular permeability at the site of blastocyst attachment has been demonstrated to be a requirement for implantation in many species (Gouge et al., 1998). Nitric oxide is an important factor involved in the initiation of implantation due to its ability to increase blood flow (Gouge et al., 1998). Nitric oxide is produced in pre-implantation embryos, and its production is required for normal embryonic development (Gouge et al., 1998). In addition to nitric oxide's ability to regulate embryonic development, the embryo may also produce nitric oxide as a signal to the uterus to stimulate local vasodilation and capillary permeability required for successful implantation (Gouge et al., 1998). In the present study, rumen-protected arginine supplementation increased peak systolic velocity in the CL for 360 ARG and 90 ARG compared to CON on d 12 of the estrous cycle. These findings are similar to previous research (Luther et al., 2008), in which vascular resistance in the ovarian artery was reduced on d 12 following L-arginine injection.

Polyamines and nitric oxide are important for placental growth and angiogenesis. More specifically, they are essential for cellular proliferation and differentiation (Wu and Morris, 1998). The enzyme arginase regulates the availability of arginine for the synthesis

Table 1. Effects of supplemental, rumen-protected L-arginine on serum amino acid (AA) concentration in Dorset ewes from d 8 to d 12 of the estrous cycle.

	Dietary Arginine, mg/kg BW[1]					
Serum AA[2]	0	90	180	360	SEM[3]	P-value[4]
Day 8						
Total essential AA, nmol/mL	1,030	915	938	949	82	0.78
Total AA, nmol/mL	2,447	2,196	2,264	2,360	163	0.72
Arginine, % of total essential AA	15.5	15.1	15.0	16.4	1.3	0.86
Arginine, % of total AA	6.43	6.32	6.08	6.55	0.49	0.92
Day 10						
Total essential AA, nmol/mL	1,085	920	973	1,081	79	0.39
Total AA, nmol/mL	2,600	2,323	2,422	2,599	187	0.66
Arginine, % of total essential AA	15.6	14.4	15.6	15.0	1.1	0.83
Arginine, % of total AA	6.47	5.70	6.13	6.27	0.39	0.54
Day 11						
Total essential AA, nmol/mL	987	932	895	1,055	63	0.34
Total AA, nmol/mL	2,502	2,345	2,260	2,464	125	0.51
Arginine, % of total essential AA	15.7	14.3	16.4	16.8	0.9	0.29
Arginine, % of total AA	6.19[a]	5.70[a]	6.44[ab]	7.16[b]	0.34	0.04
Day 12						
Total essential AA, nmol/mL	936[ab]	828[a]	809[a]	1,014[b]	58	0.08
Total AA, nmol/mL	2,320	2,057	2,037	2,378	118	0.12
Arginine, % of total essential AA	15.9	15.0	16.1	16.6	0.9	0.62
Arginine, % of total AA	6.21	5.99	6.34	7.02	0.32	0.15
Day 13						
Total essential AA, nmol/mL	963	943	885	1,028	95	0.77
Total AA, nmol/mL	2,430	2,384	2,260	2,443	185	0.89
Arginine, % of total essential AA	16.1	15.9	16.5	17.1	0.9	0.80
Arginine, % of total AA	6.34	6.19	6.37	7.14	0.35	0.26

[1] Treatments: 0, 90, 180, and 360 mg/kg BW of rumen-protected L-arginine supplemented from d 8 to d 12 of the estrous cycle (n = 5, 4, 5 and 5 respectively).
[2] Day refers to day of estrous cycle (day 0 = estrus). An initial sample taken on d 8 prior to rumen-protected arginine supplementation.
[3] Standard error of mean.
[4] P-value for F-test for treatment.
[a, b] Means with different superscripts differ *($P \le 0.10$)* within row.

of ornithine. Polyamines are synthesized from ornithine via ornithine decarboxylase (ODC) and arginase. In the current study, no differences were observed in circulating serum ornithine concentration.

Several studies have reported that low concentrations of progesterone can lead to a greater incidence of embryonic loss in sheep and ultimately result in decreased ewe productivity (Casida and Warwick, 1945; Dixon et. al., 2007). Although rumen-protected arginine in the present study exhibited stimulatory effects on ovarian hemodynamics, it did not affect serum progesterone concentrations, which is in contrast to our previous data on intravenous arginine supplementation (Luther et al., 2008). Additionally, we cannot explain why the treatments did not respond in a linear fashion. In many cases the 180 mg/kg treatment responded similar to the 0 mg/kg treatment, instead of in a linear fashion with the 90 and 360 mg/kg treatments.

Conclusions

Results of this study indicate that rumen-protected arginine supplemented to ewes may increase circulating serum-arginine concentration in addition to increasing ovarian blood flow. These preliminary data indicate that biological responses to rumen-protected arginine may be obtained without changing circulating arginine concentration. Additional research is needed to determine the potential of rumen-protected arginine as a component of strategic supplementation programs. Moreover, the ability of rumen-protected arginine to successfully reach the small intestine and enter circulation needs to be determined *in vivo*.

Table 2. Effects of supplemental rumen-protected L-arginine on ovarian hemodynamics in Dorset ewes from d 8 to d 12 of the estrous cycle

Hemodynamics	Dietary Arginine, mg/kg BW[1] 0	90	180	360	SEM[2]	P-value[3]
Corpus luteum						
Peak systolic velocity, cm/s	22.6[a]	32.5[b]	28.4[ab]	30.5[b]	2.4	0.07
Pulsatility index[4]	0.32	0.39	0.30	0.33	0.04	0.48
Resistance index[5]	0.26	0.32	0.25	0.28	0.03	0.42
Mean velocity, cm/s	20.1[a]	26.7[b]	24.4[ab]	25.7[b]	1.9	0.13
Flow time, ms	566[a]	596.00[a]	489[a]	753[b]	61	0.06
Hilus						
Peak systolic velocity, cm/s	31.3	22.3	31.9	29.0	3.3	0.21
Pulsatility index[4]	0.40	0.51	0.40	0.47	0.046	0.30
Resistance index[5]	0.32	0.39	0.31	0.37	0.027	0.18
Mean velocity, cm/s	25.1[b]	17.0[a]	25.8[b]	22.5[ab]	2.5	0.12
Flow time, ms	579[a]	595[a]	514[a]	736[b]	43	0.02

[1] Treatments: 0, 90, 180, and 360 mg/kg BW of rumen-protected L-arginine supplemented from d 8 to 12 of the estrous cycle (n = 5, 4, 5 and 5 respectively).
[2] Standard error of mean.
[3] *P-value* for F-tests for treatment.
[4] Pulsatility index = (Peak systolic velocity – End diastolic velocity) / Time-averaged maximum velocity.
[5] Resistance index = (Peak systolic velocity – End diastolic velocity) / Peak systolic velocity.
[a, b] Means with different superscripts differ ($P < 0.10$) within each row.

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Sulfur Intake, Excretion, and Ruminal Hydrogen Sulfide Concentrations in Lambs Fed Increasing Concentrations of Distillers Dried Grains with Solubles

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Summary

The objective of this research was to evaluate the effects of increasing dietary concentration of DDGS on S intake, excretion, and ruminal H_2S gas concentrations in lambs. Sixteen wether lambs (36.7 kg ± 2.3 kg) were utilized in a completely randomized design. Treatments were based on increasing concentrations of DDGS in the final finishing diet and included: 1) 0 percent DDGS, 2) 20 percent DDGS, 3) 40 percent DDGS, and 4) 60 percent DDGS. Ruminal H_2S concentrations were measured weekly via rumen puncture as lambs were adapted to their respective finishing diets. Feed, water, feces, and urine were collected over a 10 d collection period. Hydrogen sulfide gas concentrations did not differ ($P \geq 0.24$) until d 7 when lambs fed increasing concentrations of DDGS had a linear increase ($P = 0.009$) in ruminal H_2S concentrations. Linear increases ($P < 0.001$) in ruminal H_2S concentrations were also observed on d 14, d 28, and d 35 in lambs fed increasing concentrations of DDGS. Dietary DDGS inclusion did not affect DMI (1.37 ± 0.07 $kg \cdot hd^{-1} \cdot d^{-1}$; $P = 0.25$). Sulfur intake from feed and water, as well as S excretion in feces and urine increased linearly ($P \leq 0.009$) with increasing DDGS inclusion. Sulfur retention increased linearly ($P = 0.02$) with increasing inclusion of DDGS, although this does not reflect losses due to H_2S. Increasing concentration of DDGS in the diet did not result in the occurrence of PEM. This research suggests that lambs excrete substantial amounts of S from DDGS and that water intake and urinary output increase with increasing S intake.

Key Words: Distillers Dried Grains with Solubles, Lambs, Polioencephalomalacia, Sulfur, Water Intake

Introduction

Feeding increased concentrations of distillers dried grains with solubles (DDGS) to ruminants has been avoided, due to risks of S toxicity and concerns about animal performance. High S diets can cause polioencephalomalacia (PEM) in ruminants (Gould, 1998). However, research has demonstrated that lambs fed 60 percent DDGS did not develop PEM (Neville et al., 2010a) and performed similarly to those fed lesser concentrations of DDGS (Schauer et al., 2008). The data reported by Schauer et al. (2008) and Neville et al. (2010a) provide an opportunity for increased utilization of DDGS in lamb-finishing rations. However, this research stands in contrast to other findings in lambs (Low et al., 1996) and beef cattle (Zinn et al., 1999; Lamm et al., 2010), which characterize dietary S as a primary cause of PEM. The recommendations outlined by NRC (2005) list 0.3 percent S as the maximum tolerable level for ruminants consuming high-concentrate diets. Elucidating the mechanism by which lambs fed 0.7 percent S did not develop PEM (Neville et al., 2010a) is important to the livestock industry and could potentially increase the utilization of DDGS in lamb finishing rations.

Feed and water are the two sources of dietary S. Sulfur is primarily excreted as sulfate in the urine or as organic S in feces (Underwood and Suttle, 1999) or eructated as hydrogen sulfide (H_2S; Dougherty et al., 1965). Research exploring how animals adapt to excess S concentrations is limited in the literature and additional research is warranted.

We hypothesized that feeding increased concentrations of DDGS would alter intake and excretion patterns in lambs. Further, we hypothesized that feeding increased concentrations of DDGS would increase ruminal H_2S concentrations. The objective of this study was to evaluate the effects of increasing dietary concentration of DDGS on S intake, excretion, and ruminal H_2S gas concentrations in lambs.

Materials and Methods

All animal care and handling procedures were approved by the North Dakota State University Animal Care and Use Committee prior to the initiation of the research.

Animals and Treatments.

Sixteen western, white-faced Rambouillet wether lambs (36.7 kg ± 2.3 kg) were utilized in a completely random design to evaluate the effects of increasing dietary concentration of DDGS on S intake, excretion, and ruminal H_2S gas concentrations in lambs. Treatments were based on increasing concentrations of DDGS in the final finishing diet and included: 1) 0 percent DDGS, 2) 20 percent DDGS, 3) 40 percent DDGS, and 4) 60 percent DDGS. Distillers dried grains with solubles contained 27.45 percent CP, 33.65 percent NDF, 7.57 percent ADF, 0.10 percent Ca, 1.03 percent P, and 0.97 percent S. Lambs were vaccinated for clostridial disease (Covexin 8, Schering-Plough, Kenilworth, N.J.) two weeks prior to weaning, at weaning, and again at the initiation of the study. Additionally, lambs were treated for coccidiosis beginning at weaning for 10 d with Corid (9.6 percent Amprolium, Merial, Ltd., Duluth, Ga.). The diets fed from weaning to the initiation of the study are presented in Table 1 and did not contain DDGS. Treatment diets were formulated to meet or exceed CP requirements; NE was formulated for a 40 kg lamb gaining 400 g/d (NRC, 2007; Table 2). The dietary treatments were formulated to provide minimum Ca to P ratio of 1.5:1, with copper sulfate (0.002 percent, DM basis) and ammonium chloride (0.5 percent, DM basis) added to all diets to aid in the prevention of copper deficiency and urinary calculi, respectively. Thiamine was included in all diets to provide 150 mg/lamb daily using a predicted DMI of 1.36 kg.

Ruminal Hydrogen Sulfide Sampling

Ruminal H_2S gas concentrations were measured weekly via rumen puncture, as lambs were adapted from a medium-concentrate diet to their respective high-concentrate finishing rations. On d 0, lambs began the dietary adaptation period, which increased the concentrate portion of the diet to 85 percent over 28 d (Table 3). Hydrogen sulfide measurements were collected on d -7, d 0, d 7, d 14, d 21, d 28, and d 35 of the adaptation period. Ruminal fluid was also collected via rumenocentesis at the same time ruminal gas-cap samples were collected. Ruminal pH was determined immediately with a combination electrode (model 2000 pH/temperature meter; VWR Scientific Products, West Chester, Pa.). Ruminal H_2S and fluid samples were collected 4 h after feed was offered.

Procedures for ruminal gas-cap sampling were adapted from those of Gould et al. (1997). In order to obtain ruminal gas-cap samples, wool was shorn from a 15 cm by 15 cm area of the animal's left side immediately posterior to the 13th rib. Shearing was done with surgical clippers with care taken to remove all wool. After shearing, this area was scrubbed and disinfected with alternating isopropyl alcohol and Betadine scrubs. In order to accomplish multiple samples while maintaining the integrity of the rumen gas, two separate portions of the sampling apparatus were developed (Neville et al., 2010a). The first portion included the 7.6 cm 12-gauge needle, which was connected to a 20-cm (4.75 mm diam.) tubing (Tygon ®, S-50-HL Class VI) via a Luer-lock connection. The second portion of the sampling apparatus included a 140 mL catheter-tip

Table 1. Diets fed to lambs prior to initiation of research diets (%, DM basis).

Ingredient	Weaning	2 wk Post-Wean	4 wk Post-Wean	6 wk Post-Wean
Creep Pellet[1]	100	50	25	--
Alfalfa	--	15	20	20
Dry Rolled Corn	--	20	30	50
Barley	--	15	25	30

[1] Creep pellet contained: 16% CP, 3.5% crude fat, 12% crude fiber, 1% Ca, 0.55% P, 0.5% salt, 0.2 mg/kg Se, 5,730 IU/kg vitamin A, 573 IU/kg vitamin D, 22 IU/kg vitamin E, and 50g/ton chlortetracycline.

Table 2. Ingredient and nutritional composition of lamb diets.

Item	Diet[1]			
	0% DDGS	20% DDGS	40% DDGS	60% DDGS
	DM basis			
Ingredient, %				
Alfalfa Hay	15.00	15.00	15.00	15.00
Dry Rolled Corn	81.38	61.38	41.38	21.38
DDGS[2]	0.00	20.00	40.00	60.00
Ammonium Chloride	0.5	0.5	0.5	0.5
Limestone	2.25	2.25	2.25	2.25
Lasalocid[3]	0.085	0.085	0.085	0.085
TM package[4]	0.78	0.78	0.78	0.78
Copper Sulfate	0.002	0.002	0.002	0.002
Thiamine	0.011	0.011	0.011	0.011
Nutrient composition (analyzed)				
CP, %	14.0	19.4	22.0	24.7
NDF, %	23.7	27.6	30.6	31.8
ADF, %	10.1	11.0	11.1	11.5
S, %	0.22	0.52	0.70	0.84
Ca, %	1.72	1.64	1.35	1.16
P, %	0.50	0.65	0.77	0.81
Cu, mg/kg	19	19	15	17
Zn, mg/kg	59	95	90	73
Thiamine[5], mg/kg	70.8	67.2	55.5	51.5

[1] Diets were balanced to meet or exceed requirements set by (NRC, 2007). Treatments based on distillers dried grains with solubles inclusion: 1) 0% DDGS, 2) 20% DDGS), 3) 40% DDGS, 4) 60%DDGS.
[2] Distillers dried grains with solubles.
[3] Lasalocid (Bovatec 68, Alpharma Inc., Fort Lee, NJ).
[4] Trace Mineral (TM) package contained: 11.7% Ca, 10.0% P, 14% salt, 0.1% K, 0.1% Mg, 20 mg/kg Co, 100 mg/kg I, 2,450 mg/kg Mn, 50 mg/kg Se, 2,700 mg/kg Zn, 661,500 IU/kg Vitamin A, 66,150 IU/kg Vitamin D3, and 1,320 IU/kg Vitamin E.
[5] Formulated based on estimated feed intake of 1.36 $kg \cdot hd^{-1} \cdot d^{-1}$, with a target of 150 mg/lamb daily intake of thiamine.

syringe (Monoject, Sherwood Medical, Ballymoney, N. Ireland), which was connected to an 8-cm (4.75 mm diam.) portion of tubing via Luer-lock connection. The two portions were then connected or disconnected through Luer-lock connections with ratchet tubing clamps utilized on both sides of the Luer-lock connectors. After the needle was introduced through the skin and into the rumen gas cap, a 120 mL sample (approximately) of ruminal gas was drawn into the syringe. The first of two syringes was then disconnected and a second filled in the same manner. Hydrogen sulfide gas detector tubes (Gastec©, Kanagawa, Japan) were connected to a volumetric, gas-sampling pump and a volume (100 mL) was drawn through the detector tube to acquire a measurement of ruminal gas-cap H_2S. At each sampling point duplicate measurements were taken from each lamb, and the average of the two samples was used for any calculations. If the detector tube failed to reach 100 ppm H_2S (the lowest detectable concentration recommended by the manufacturer) the reading was recorded as a zero and 'zero' used for all mean calculations. Following gas and fluid sampling, the needle was removed, and the sampling site was sprayed with a 10-percent iodine solution. Lambs were then given injections of penicillin (3 mL/d; Pro-Pen-G, Bimeda Inc., LeSueur, Minn.) for three consecutive d following sampling to prevent peritonitis. Ruminal H_2S concentrations were converted from parts per million to grams per cubic meter H_2S through the following equation: H_2S (g/m^3) = [(H_2S (ppm) × 139.06)/1000000] assuming standard temperature and pressure values (Neville et al., 2010a).

Sulfur Intake and Excretion

On d 35, lambs were placed into metabolism crates and adapted to the crates for 10 d. Following adaptation, lambs were fitted with fecal-collection bags. Samples of feed, water, feces, and urine were collected over a 10 d period at 0700 each d. Feed intake was recorded daily, with daily adjustments made to target ad libitum intake (10-percent feed remaining). Ort samples were collected, weighed, and dried before being composited on an equal weight basis (10 g/d) within lamb for laboratory analysis. Water was provided twice daily. Water intake was calculated by subtracting any unconsumed water measured (volume) from water offered. Daily water samples were collected and frozen (-20°C) before being composited for laboratory analysis of water sulfates. Water was analyzed for sulfate (93 mg/L) by a commercial laboratory (Stearns DHIA, Sauk Centre, Minn.). Fecal bags were emptied daily, total feces weighed and 10-percent wet weight added to a composite sample, which was frozen (-20°C) for later analysis. Plastic buckets (3.78 L) were placed beneath false-bottom metabolism crates to facilitate collection of urine. Urine buckets were acidified with 150 mL hydrochloric acid (50 percent w/v) to inhibit microbial growth and prevent volatilization. Urine output was filtered through four layers of cheesecloth before volume (mL) and weight (g) were recorded; a 10 percent subsample of urine weight was composited and frozen for later analysis.

Laboratory Analysis

Feed and ort samples were dried using a forced-air oven (55°C; The Grieve Corporation, Round Lake, Il.) for 48 h. Dried samples were ground using a Wiley Mill (Arthur H. Thomas Co., Philadelphia, Pa.) to pass a 2 mm screen. Feed samples were analyzed for DM, ash, N, P; and Ca, Cu, and Zn (methods 934.01, 942.05, 2001.11, 965.17; and 968.08 respectively; AOAC, 2010). Concentrations of NDF (Van Soest et al., 1991; as modified by Ankom Tech-

Table 3. Adaptation diets (%, DM basis) fed to lambs on d 0 - 28.

	Diet				
	Step 1	Step 2	Step 3	Step 4	Step 5
	d				
Ingredient	**0**	**7**	**14**	**21**	**28**
0% DDGS					
Alfalfa Hay	46	46	35	25	15.0
Dry Rolled Corn	50.4	50.4	61.4	71.4	81.4
DDGS[1]	0	0	0	0	0
Supplement[2]	3.6	3.6	3.6	3.6	3.6
S (%, DM basis)	0.24	0.23	0.25	0.20	0.22
20% DDGS					
Alfalfa Hay	46	46	35	25	15
Dry Rolled Corn	50.4	45.4	51.4	56.4	61.4
DDGS[1]	0	5	10	15	20
Supplement[2]	3.6	3.6	3.6	3.6	3.6
S (%, DM basis)	0.31	0.35	0.41	0.39	0.52
40% DDGS					
Alfalfa Hay	46	46	35	25	15
Dry Rolled Corn	50.4	40.4	41.4	41.4	41.4
DDGS[1]	0	10	20	30	40
Supplement[2]	3.6	3.6	3.6	3.6	3.6
S (%, DM basis)	0.39	0.45	0.60	0.59	0.70
60% DDGS					
Alfalfa Hay	46	46	35	25	15
Dry Rolled Corn	50.4	35.4	31.4	26.4	21.4
DDGS[1]	0	15	30	45	60
Supplement[2]	3.6	3.6	3.6	3.6	3.6
S (%, DM basis)	0.41	0.60	0.69	0.70	0.84

[1] Distillers dried grains with solubles.
[2] Supplement contained (% total diet): 0.5% ammonium chloride, 2.25% limestone, 0.085% Lasalocid (Bovatec 68), 0.78% trace mineral, 0.002% copper sulfate, and 150 $mg \cdot hd^{-1} \cdot d^{-1}$ thiamine.

nology, Fairport, N.Y.) and ADF (Goering and Van Soest, 1970, as modified by Ankom Technology, Fairport, N.Y.) were determined using an Ankom 200 Fiber Analyzer (Ankom Technology, Fairport, N.Y.)) without sodium sulfite, with amylase, and without ash corrections as sequentials. Sulfur and thiamine were analyzed by Inductively Coupled Argon Plasma and AOAC procedure 942.23/HPLC, respectively, by a commercial laboratory (Midwest Laboratories, Omaha, Neb.).

Statistical Analysis

Hydrogen sulfide gas and pH data were analyzed utilizing the repeated measures analysis in the Mixed Procedures of SAS (SAS Inst. Inc., Cary, N.C.) with *P*-values ≤ 0.05 considered significant. Treatment, day, and the treatment by day interaction were evaluated. The covariate structure used was autoregressive [AR(1)]. Other structures were tested; however autoregressive was the best fit based on fit statistics. Sulfur intake and excretion data were analyzed as a completely randomized design using the Mixed procedures of SAS with lamb serving as the experimental unit. The model included treatment. Linear and quadratic contrasts were used to evaluate the effect of increasing concentration of DDGS inclusion. Significance was declared at $P \leq 0.05$.

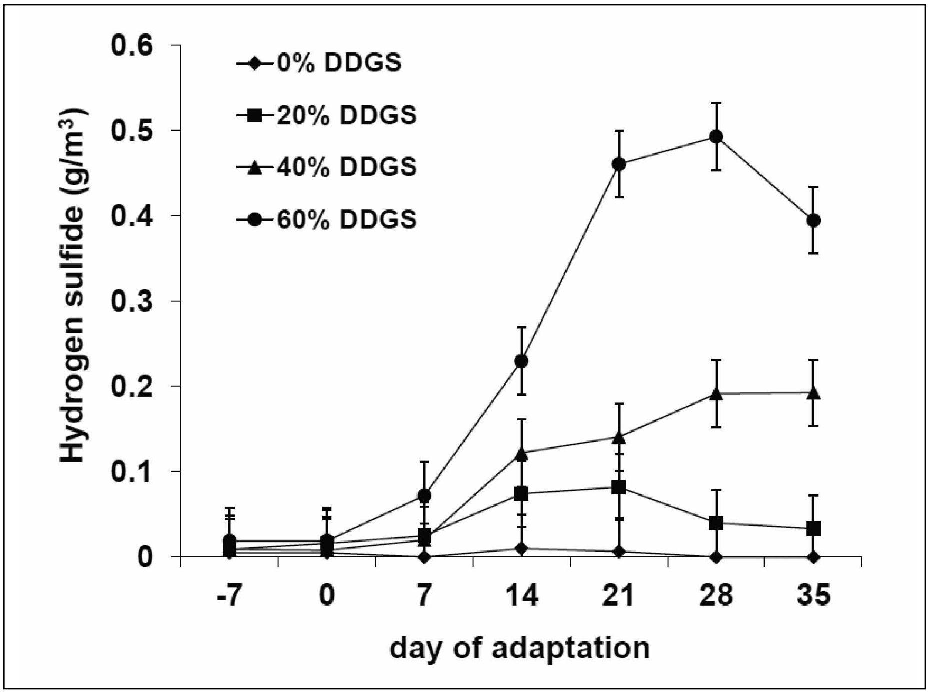
Results and Discussion

Ruminal pH and Hydrogen Sulfide Concentration

Hydrogen sulfide gas concentration was affected by treatment, day, and a day by treatment interaction ($P < 0.001$; Figure 1). Hydrogen sulfide gas concentrations did not differ ($P \geq 0.24$) until d 7 when lambs fed increasing concentrations of DDGS had a linear increase ($P = 0.009$) in ruminal H_2S concentrations. Linear increases ($P < 0.001$) in ruminal H_2S concentrations were also observed on d 14, d 28, and d 35 in lambs fed increasing concentrations of DDGS. A quadratic increase ($P < 0.001$) in ruminal H_2S concentration was observed on d 21. Ruminal pH (data not shown) was not affected by a day x treatment interaction ($P = 0.65$) or by treatment ($P = 0.32$), but decreased ($P < 0.001$) across the adaptation phase from 5.82 (d -7) to 5.33 (d 35).

Lambs fed 60-percent DDGS in the present study had ruminal H_2S concentrations nearly half of those reported by Neville et al. (2010a) in finishing lambs fed diets similar in dietary and nutrient composition. Water sulfate concentrations were 74 mg/L and 93 mg/L for Neville et al. (2010a) and the present study, respectively, so it is unlikely differences in water sulfate contributed greatly to the differences between the studies. Dietary S concentrations for the 60-percent DDGS treatment in the two studies were 0.71 percent and 0.84 percent S for Neville et al. (2010a) and the present study, respectively. Given that dietary S concentrations (from feed and water) as well as feeding regimen and dietary adaptation were similar for both studies, the differences in H_2S concentrations between the two studies may be a result of differences in sulfate reducing bacteria population in the rumen. Another potential explanation could be differences in form of S in the diet. While we did not measure the various forms of S (amino acids, sulfate, etc.) for each diet, differences in S form may be occurring. Further, the current study also shows decreases in ruminal pH coincide with increasing ruminal H_2S concentrations, which supports previous research. Gould (1998) suggested that sulfide in rumen fluid, ruminal fluid pH, frequency of eructation, and absorption of sulfide through

Figure 1. Influence of increasing concentrations (g/m^3) of distillers dried grains with solubles DDGS on ruminal H_2S concentrations in lambs. *P*-values for effect of treatment ($P < 0.001$), day ($P < 0.001$), and treatment by day interaction ($P < 0.001$). Treatment diets were based on increasing the concentration of DDGS (0, 20, 40, or 60% of dietary dry matter). Concentrations of H_2S gas measured via rumenocentesis in H_2S detector tubes (Gastec, Kanagawa, Japan).



the rumen mucosa may explain differences in ruminal H_2S concentrations.

Sulfur Intake and Excretion

In our study, level of dietary DDGS inclusion did not affect DMI (1.37 ± 0.07 kg·hd^{-1}·d^{-1}; $P = 0.25$; Table 4). Zinn et al. (1997) reported that increasing levels of ammonium sulfate affected DMI and ADG in feedlot cattle. Kandylis (1984) also reported a number of studies in both beef cattle and lambs that demonstrated DMI was reduced when feeding 0.3 percent to 1.2 percent dietary S from either inorganic and organic sources. Qi et al. (1993) reported that DMI of growing goats peaked when dietary S was 0.2 percent. The present study contradicts these findings in that increasing S from DDGS did not result in decreased intake when dietary S exceeded 0.22 percent. However, the source of S (calcium sulfate vs. DDGS), as well as the range of S concentration evaluated, likely influenced these findings and explain in part differences between Qi et al. (1993) and the present study. Another possible explanation for these discrepancies is differences in dietary ingredients. Most importantly, Qi et al. (1993) included 1.5 percent urea-N which resulted in a N:S ratio of 10:1. This is the recommended ratio for lambs (NRC, 2007). The 10:1 ratio is recommended to ensure enough S is present to allow for microbial production of S-amino acids when urea-N is included in the diet. In the present study, our N:S ratios were 10:1, 6:1, 5:1, and 4.7:1 for the 0, 20, 40, and 60 percent DDGS diets, respectively. Zinn et al. (1997) also indicated differences in ruminal and total tract availability of S may influence animal performance. The present study, along with results of Schauer et al. (2008), indicate diets which include up to 60-percent DDGS (percent, DM basis) do not result in reduced DMI or growth performance in growing and finishing lambs. Decreases in ruminal and intestinal motility (Bird, 1972; Kandylis, 1984) could explain the decreased DMI observed with increasing DDGS inclusion in other studies. Loneragan et al. (2001) hypothesized that either decreased gut motility or hepatic injury may reduce animal performance. Liver function was not assessed in the present study; therefore it is possible that liver metabolism could have been impacted. Data from a concurrent project (Neville et al., 2010b) found no liver abscess in steers fed increasing concentrations of DDGS (dietary S levels > 0.6 percent S). However, presence of liver abscesses may be dependent on rate of dietary adaptation and use of antimicrobial compounds such as tylosin (Nagaraja and Chengappa, 1998; Vasconcelos and Galyean, 2008) and should not be viewed entirely as an indicator of liver function.

Sulfur intake from feed and water, as well as S excretion in feces and urine increased linearly ($P \leq 0.009$) with increasing DDGS in the diet. Lambs fed 60 percent DDGS had water intakes 54 percent greater than those fed no DDGS ($P < 0.01$). Increased water intake resulted in an increase of 3-fold in urine volume and a 4.8-fold increase in urinary S excretion ($P < 0.01$) compared to lambs fed no DDGS. Multiple factors could be responsible for the increased water intake, including sulfur, sodium, or nitrogen content of the DDGS. Given the water intake and urine output data, ad libitum access to low-sulfate water may be key to increasing S tolerance when high amounts of DDGS are fed to growing and finishing lambs. Sulfur is primarily excreted as sulfate in the urine or as organic S in feces (Underwood and Suttle, 1999). Sulfur retention increased linearly ($P = 0.004$) with increasing inclusion of DDGS in finishing diets. Actual S balance is not reported as the total volume of eructated H_2S gas was not measured. Digestibility of S did not differ ($P = 0.62$) with S digestibility equaling 44.6 percent, 46.1 percent, 36.8 percent, and 45.0 percent for 0 percent, 20 percent, 40 percent, and 60 percent DDGS diets, respectively. As stated earlier, we did not measure the volume of gas eructated, but it is likely that substantial amounts of S were also excreted via eructation. Further research is needed to quantify S excretion via H_2S gas by eructation. The present study serves as another example of the need to quantify H_2S lost via eructation, and more importantly, with respect to H_2S toxicity, it underscores the need to quantify H_2S inhalation after eructation.

To our knowledge there are no published reports which detail or quantify the various forms of S contained within

Table 4. Intake, excretion, and sulfur balance of lambs fed increasing concentrations of distillers dried grains with solubles.

	Treatment[1]						P-Value[3]	
Item	0% DDGS	20% DDGS	40% DDGS	60% DDGS	SEM[2]	*P*-value	Linear	Quadratic
Intake								
Feed, kg	1.3	1.5	1.4	1.3	0.07	0.25	0.68	0.06
Water, L	3.1	3.5	3.7	4.8	0.28	0.006	<0.001	0.31
Excretion								
Fecal, kg	0.20	0.23	0.27	0.25	0.02	0.17	0.06	0.33
Urine, L	0.59	0.85	1.1	2.4	0.3	0.008	0.002	0.12
DMD, %[4]	84.73	84.40	81.31	80.69	1.0	0.03	0.005	0.88
Sulfur								
Intake								
Feed, mg	2,487.5	6,076.2	7,429.4	9,029.6	816.6	<0.001	<0.001	0.25
Water, mg	94.8	109.4	115.7	148.9	8.7	0.006	0.001	0.31
Total S, mg	2,582.4	6,185.6	7,545.1	9,178.4	815.8	<0.001	<0.001	0.25
Excretion								
Feces, mg	761.4	947.6	1,112.1	1,130.5	90.6	0.05	0.009	0.37
Urine, mg	674.9	2,370.8	3,236.0	3,945.1	268.8	<0.001	<0.001	0.09
Total S, mg	1,436.3	3,318.4	4,348.0	5,075.6	344.5	<0.001	<0.001	0.12
Retention, mg	1,146.1	2,867.2	3,197.1	4,102.8	568.0	0.02	0.004	0.49

[1] DDGS = Distillers dried grains with solubles.
[2] n = 4.
[3] *P*-value for linear and quadratic effects of increasing concentration of DDGS in diet.
[4] DMD = Dry matter digestibility.

DDGS. Quantifying proportions of the various forms of S will undoubtedly add to the current literature and assist in determination of mechanisms of S toxicity in the ruminant animal. Additionally, determining how digestibility or availability of S in its various forms influences S reduction and creation of H_2S gas within the rumen will further aid in the understanding of S-toxicity mechanisms.

Kandylis (1984) reported that H_2S present in the rumen may cause neurological or respiratory distress. As in our previous research (Neville et al., 2010a), we did not observe any outward clinical signs of PEM. Hydrogen sulfide is reported in two forms in the literature either concentration of H_2S in rumen gasses, or production of H_2S from ruminal fluid, as in *in vitro* studies. The present study reports H_2S in terms of concentration. The values for S retention in the present study give some indication of the quantity of H_2S excreted by the animal. However, it should be noted that H_2S data and S-metabolism data were collected at different time points, and changes in either aspect could alter interpretation. These data do not account for the use of S in production of wool, muscle tissue, or other protein (S-amino acid) production, which also impacts calculations of S retention.

Conclusions

Increasing concentration of DDGS in the diet increased S intake, excretion, and H_2S gas concentrations but did not result in any clinical signs of PEM. However, the length of the feeding study may not have been great enough to allow for PEM to occur. Additionally, the inclusion of thiamine in the treatment diets may have prevented the occurrence of PEM. The research reported here indicates S excretion increased with increasing dietary S concentrations and, in part, explains why S toxicity did not occur even though dietary S concentrations were well in excess of the NRC maximum tolerable level for ruminants. Continued efforts to quantify H_2S production will add to the body of knowledge regarding S metabolism and excretion. The present study, along with previous research at our institution, has demonstrated that feeding up to 60-percent, dietary DDGS concentrations is possible without affecting lamb health or performance. Defining the role of various S sources as determining factors in S tolerance is needed. Accounting for digestibility or availability of various S sources will facilitate a more appropriate definition of both maximum tolerable and toxic levels of S in future recommendations.

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Effects of Season of Kidding on Doe Performance in Commercial Boer Cross Does[1,2]

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Summary

Little information is available on the impact of season of kidding on doe performance in goats. However, many producers in the southeastern United States kid in the late fall and winter because of seasonal market trends. Weather conditions during this time tend to require higher labor and nutritional supplementation. Because of this, a study was designed to evaluate doe performance by comparing total birth, 60 d and 90 d kid weight, doe efficiency ratio, conception rate, and kid survival to weaning in two alternative kidding seasons. One hundred and twenty commercial, meat-type does were randomly assigned to either a fall (October - December) or spring (March - May) kidding season. Data collected included birth weight, birth type, sex, 60 d weight, and 90 d weight on the kids. Doe weight and body condition score were taken at weaning (90 d), and the efficiency ratio was calculated by dividing the total weight of kids at 90 d by the doe weight taken at weaning. Kidding season had an effect ($P < .01$) on doe weight at weaning, total weight at 90 d, and conception rate. Season of birth did not affect total birth weight ($P = .21$) or total 60 d weight ($P = .38$). Doe weight and total 90 d weight were higher for fall than spring kidding; however, conception rate was higher for spring kidding does. This research indicates that kidding season has an influence on total weaning weight per doe. However, differences in conception rate may decrease profitability of fall and early winter kidding herds.

Key Words: Meat Goat, Season of Birth, Doe Efficiency Ratio

Introduction

Analysis of meat-goat, auction-market prices, have shown seasonal price differences with higher prices being seen in the spring when supply is generally low and several ethnic holidays increase demand. Many producers are breeding to target the market peaks around these ethnic holidays (Coffey, 2002). To do this, many producers have started breeding for fall and winter kids. However, little information is available on differences in conception rates, twinning rates, and doe productivity related to different seasons of birth in goats. Wilson and Light (1986) did find a seasonal effect on number born, total weaning weight, and survival in kids and lambs in Mali. Other research with cattle and sheep has also shown differences in weaning weight and breeding success for different calving and lambing seasons (McCarter et al. 1991; Gaertner et al. 1992; Lewis et al. 1996; and Casas et al, 2004). From this information, it would be reasonable to believe that goat producers may be impacting productivity by changing to a fall kidding season. Because of the work in other species and the limited information in goats, this project was designed to determine the effect of fall and spring kidding season on 1) doe performance; 2) conception rate; and 3) kidding rate in a group of commercial, Boer-cross, meat goats.

Materials and Methods

A total of 120 commercial, meat-type does were available each year for the three years of this project. The does were part of the herd at the Kentucky State University Research and Demonstration Farm (KySU), Frankfort, Kentucky; Latitude: 38.12, Longitude: 84.88, elevation: 228.14 m All does were bred to registered Boer bucks to produce kids in either the fall (October – December) or spring (March – May). Breed and age records were not available on the doe herd at the start of the project.

Due to differences in nutritional demands, does were managed separately from kidding to weaning and from four weeks before to two weeks after breeding. A flushing period was started four weeks before the start of the breeding season, and goats were not placed back into a single group until two weeks after the end of breeding. At kidding time does were separated starting four weeks before the start of the kidding season so they could be supplemented to meet their nutritional needs. The same supplement program was used and amounts were based on nutritional needs and forage quality.

Does were randomly selected using a gate cut between the two breeding season treatment groups. There were no available records to determine age of the doe herd, mouthing of animals revealed very few animals under 2 years of age so age of dam was not standardized between groups. All goats remained in the assigned treatment group for the three years of this project. All does were exposed by natural service for a 60-day breeding season with target kidding dates of October 15 to December 15 for the fall kidding season, and March 15 to May 15 for the spring kidding season.

All bucks used were registered Boer bucks. Each buck was used in both seasons to reduce sire effects on growth. Bucks were randomly assigned to single-sire breeding pastures at the start of each breeding season. After 30 days sires were rotated to different single sire breeding pastures to reduce potential issues of fertility and libido on conception rates. Three bucks were used each year of the project and each buck produced kids in each season. Bucks were replaced as necessary due to injury or death through the study. A total of seven bucks were used in the project. At no point were all sires replaced at any single time, and one sire was used in each season through the entire project.

The does were maintained on tall fescue (*Lolium arundinaceum*) pastures during the year with a small amount of native warm-season grass available during the summer. In September, all does were placed on standing corn (*Zea mays*), when it reached the hard-dough stage of maturity, for six weeks shortly before fall kidding and breeding started. Does were fed a commercial pellet feed; produced by Bagdad Roller Milles, Bagdad, Ky., as needed to meet nutritional demands. The feed contained monensin to help control coccidia. Nutritional composition, provided by the manufacture, of the pellet is shown in Table 1. Hay-quality analysis were done each year, and the amount of supplement was adjusted to meet doe needs based on NRC recommendations. All other supplemental feeding was conducted based on forage availability and standard production practices. All does had access to free-choice minerals at all times. Fescue hay was provided, free choice, when necessary due to drought and for winter feeding.

Fall kidding does were flushed by supplementing with 0.34 kg of the pellet feed starting four weeks before breeding until two weeks after the end of the breeding season. The spring kidding does were not supplemented before the start of the breeding season, as they had access to the standing corn before the start of the breeding season. They received the same supplementation as the fall kidding does at the start of each breeding season until two weeks after the end of the breeding season.

Table 1. Nutritional composition of pellet feed.

Nutrient	Unit	AS Fed	Dry Matter
DM	%	89.78	100
Net Energy Main	mcal/lb	0.76	0.84
Net Energy Gain	mcal/lb	0.50	0.56
TDN	%	67.76	75.47
CP	%	15.02	16.73
Digestible Protein	%	12.19	13.58
NPN	%	0.82	0.92
ADF	%	19.32	21.52
NDF	%	36.55	40.72
Ca	%	0.99	1.10
P - Total	%	0.54	0.60
Vit A	kiu/lb	9.08	10.11
Vit E	iu/lb	8.59	9.57

Kids were weaned at an average age of 90 d. Kid weights were taken at birth, 60 d and 90 d. Both spring and fall born kids were creep fed, ad libitum, between 60 d and 90 d of age on the same pellet feed used to supplement the does.

Weights, eye-color score, and BCS were collected for the does at monthly weigh dates during the year except for two months during kidding. Birth and weaning weight for each kid born and raised by a doe were added together to create a doe performance record. This allowed for comparison of total weight per doe at birth, 60 days, and weaning to be evaluated. If a kid was bottle-fed, it was not included in the data set for the birth dam except for birth data. No kids were successfully grafted to another doe during the study.

Data were analyzed using Proc Mixed (SAS, Inc., Cary, N.C.). Season and project year were included as fixed effects. Age was included as a random effect for 60 d and 90 d total weight. Doe weight and BCS at weaning were used to compare doe size and condition. A doe efficiency ratio was calculated by dividing the total, actual, weaning weight by the weight of the doe at weaning. This value was used to compare efficiency of production between the two seasons.

Conception rate was calculated based on breeding and birth records. Birth weights were taken and identification numbers given to kids that were born dead or died shortly after birth to give the doe credit for the total weight carried to birth and for calculations of litter size at birth. Number of kids per doe at each weigh date was recorded and used to determine differences in survival between the two seasons of birth.

Does were culled for failure to kid, failure to wean a kid, physical injuries, and structural defects. Replacement does were added to each kidding group each year as needed. Doe kids produced in the fall and spring seasons were selected based on being born twin or triplet and for growth to weaning. These does were exposed at a year of age to kid at an average of 1.5 years. This resulted in spring-born doe kids being added to the fall-breeding herd and the fall-born doe kids being added to the spring-kidding herd. This was done to provide a greater time for maturity and to reduce some of the impact of age of dam at first kidding. Because age records were not available on the breeding herd at the start of this project, age of dam was not included in the analysis.

Results and Discussion

Number of Kids Produced

Data from this study indicated there were no significant differences for season of birth on litter size and kids per doe at 60 d or 90 d ($P = 0.21$, $P = 0.38$, and $P = 0.48$ respectively). However, there was a significant difference ($P < .0001$) due to season on conception rate with spring does having a higher conception rate than fall-kidding does (Table 2). This resulted in a significant ($P < .0001$) difference in kidding rate (kids born per doe bred) between the two seasons. There were a similar number of kids lost between birth and weaning for both kidding seasons so the number of kids per doe bred at 60 d and 90 d (Table 2) were also significantly different ($P = 0.0024$ and $P = 0.0043$ respectively).

The difference in conception rate is believed to be due to the seasonal nature of small-ruminate-estrous cycles, resulting in greater fertility during shorter day length. This is supported by research with sheep. Carter et al. (1971) reported a slight genotype-environment interaction for conception rate in ewes. Lewis et al. (1996) and Notter and Copenhaver (1980) reported that ewes had higher litter sizes when exposed during "normal" breeding seasons in an accelerated breeding program.

Season of kidding did not effect survival to weaning ($P = 0.6584$). Researchers from other countries (Hussin et.al, 1995; Ndlovu and Simela, 1996; Wilson and Light, 1986) reported differences in survival rate for kids due to season. This may be due to differences in management practices, nutrition, and seasonal weather between the United States and these countries. Perez-Razo (1998) found that kids born in October to Januray had higher survival rates than those born from April to July in Dairy breeds. Earlier reports in the United States (Shelton and Willingham, 2002) indicated that cold weather reduced lamb survival to weaning. Cold weather is more common during the spring kidding season in Kentucky than fall kidding season.

Kid Weight per doe

Total kid weight per doe did not differ between seasons for birth or 60 d weight ($P = 0.21$ and $P = 0.38$, respectively). However, we did find a significant difference ($P = .014$) for 90 d weight in this study (Table 2). The fall-kidding does produced more total-kid weight at 90 d than the spring-kidding does.

Table 2. Least square means and SE within kidding season for production traits .

Trait	N	Spring[a]	Fall[a]
Conception rate, %	360	87.8 ± 3.12^y	71.0 ± 2.91^z
# kids born/doe exposed	360	1.73 ± 0.073^y	1.34 ± 0.068^z
Litter Size/doe kidding	283	1.98 ± 0.050	1.88 ± 0.052
Total birth wt/doe kidding, kg	276	7.06 ± 0.42	10.07 ± 0.408
# kids at 60 d/doe exposed	360	1.30 ± 0.066^y	1.02 ± 0.062^z
# kids /litter at 60 d	283	1.49 ± 0.058	1.44 ± 0.060
Total 60 d wt/doe kidding, kg	256	24.26 ± 0.911	24.16 ± 0.921
Survival to 90 days, %	279	81.9 ± 2.66	81.6 ± 2.77
# kids at 90 d/doe exposed	360	1.28 ± 0.066^y	1.02 ± 0.062^z
# kids / litter at 90 d	283	1.47 ± 0.058	1.44 ± 0.060
Total 90 d wt/doe kidding, kg	255	30.52 ± 1.15^y	32.61 ± 1.16^z
Doe wt at weaning, kg	256	55.5 ± 4.41^y	66.6 ± 4.62^z
Efficiency, %	252	73.5 ± 3.08^y	61.5 ± 3.16^z
BCS (1 – 5 scale)	255	1.5 ± 0.09	1.5 ± 0.09

[a] Means are expressed in the value of the variable ± Standard Error
^{y,z} Means in the same row with different superscripts differ significantly ($P < .05$)

Other researchers have indicated a difference between growth rate in lambs and calves due to season of birth (Carter et al., 1971 and Notter et al., 1975). Delgadillo et al. (2007) reported that season of birth affected birth weight with October-born kids being heavier than those born in January and May. Marai et.al (2002) reported that in Nubian does in Egypt, total weight produced per doe lifetime was increased in does that kidded in November and December over those that kidded in February to March, but birth weight was higher for those kidding in February to March. Other research has indicated that creep feeding reduces or eliminates seasonal effects on weaning weight (Marlowe and Gaines, 1958 and Notter et al., 1975). The kids in this study were creep fed between 60 d and 90 d of age. This may have reduced the impact season of birth had on kid weight but failed to eliminate it totally due to the short duration of the creep- feeding practice. The other research was looking at individual performance that may account for some differences with this project. Further analysis is needed to determine if individual kid weights differed.

Doe Weight and Condition Scores

Doe weight at weaning (Table 2) was significantly different (*P* < *.0001*) between the two kidding groups. However, body condition score (Table 2) did not differ (*P* = *.36*). This indicated that the spring-kidding does were smaller in body size than the fall-kidding does. To confirm this, the doe weights at breeding were examined (data not shown). A similar difference was found at breeding with the fall-kidding group being heaver than spring though BCS was similar. The management practice of culling does that failed to breed for their assigned season may have removed more of the smaller does from the fall kidding herd resulting in this difference.

Doe Efficiency

Efficiency was calculated as the percent of doe-body-weight weaned. In general, larger animals have higher maintenance requirements. This results in a greater cost of maintenance for larger does. The fall-kidding does were heavier at weaning and weaned more pounds of kid per doe. This value will help determine if the amount of additional weight weaned is proportional to doe size.

Doe efficiency was significantly different (*P* < *.0001*) between spring and fall groups; however, the spring-kidding does had a higher efficiency ratio than the fall-kidding does (Table 2). This indicates that the fall-kidding does did not increase productivity proportional to their body size, making the spring-kidding herd more efficient.

Reports with cattle have shown that larger dams tend to wean larger offspring (Lemenager et al; 1980, Andries; 1992). However, Andries (1992) reported that this relationship was quadratic, indicating that larger cows may not be as efficient in productivity as smaller ones. Nichols and Whiteman (1966) saw only a small, nonsignificant correlation between yearling-ewe weight and total-lifetime-weight produced, again indicating that larger dams may not be as efficient.

Economics of Kidding Season

Price differences between months for goat kids can be very large. An analysis of price per kg for kid-slaughter goats reported by USDA-AMS over four years showed prices were highest for kid goats in February, March, April, and May ($0.49, per kg) and lowest in August, October, and November ($0.42, $0.41, and $0.42 per kg, respectively). This indicates that kids ready for market in the winter and spring bring higher prices than those ready in the fall and summer. If fall-born kids were marked at weaning in February ($0.49 per kg) and spring-born kids in June ($0.42 per kg), it would result in a $0.07 per kg price advantage for the fall-kidding group in this study. The gross income per doe was calculated by multiplying the total-weaning weight by the price per kg ($0.42 or $0.49, for spring- or fall-kidding respectively). This value was then analyzed to determine if there was a difference in gross income between fall- and spring-kidding herds.

When the data were analyzed for the whole herd, season was not significant (*P* = *04351*) for gross income. This indicates that fall- and spring-kidding herds have the potential to generate similar incomes despite the difference in price and conception rates in the fall. When the data was analyzed specifically for does that produced kids and weaned kids season was significant (*P* < *0.0001* in both analysis) with fall kidding does generating greater gross incomes. Because does kidding in the spring are able to be placed on fresh forage and reduced supplementation, spring-kidding does may have a lower cost of production compared to fall-kidding does. More research is needed to determine exact differences in cost between the two kidding groups. This will allow for better determination of profitability of the different seasons of kidding.

Conclusions

The results of this study indicate that fall-kidding does weaned more total weight per doe that kidded but had a lower conception rate than spring-kidding does. However, number of kids born per doe that kidded and survival to 90 days was not different between kidding seasons. Price paid for kids at auctions were higher in late winter and early spring when fall born kids would be marketed but the lower conception rate reduced overall income per doe exposed. More research is needed to evaluate the different cost of production between spring- and fall-kidding herds to determine which is more profitable. This study did show that conception rates appear to be the major difference in doe performance between the fall- and spring-kidding herds.

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Mixed Grazing Goats With Cattle on Reclaimed Coal Mined Lands in the Appalachian Region: Effects on Forage Standing Biomass, Forage Botanical Composition and Autumn Olive (*Elaeagnus umbellata* Thunb.)

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Summary

Reclaimed coal-mined lands in Appalachia of the United States can be successfully utilized for beef cattle but the proliferation of invasive-plant species, such as autumn olive (*Elaeagnus umbellata* Thunb.) can limit this option. An experiment was conducted in 2006, 2007, and 2008 near Wise, Va. to determine the effects of cattle-alone grazing and mixed grazing of goats with cattle on forage standing biomass, forage botanical composition, and autumn olive. After the first sampling, forage standing biomass remained higher in cattle-alone grazing ($P \leq 0.002$). Weed content was lower at the end of the grazing season in mixed grazing in all years ($P < 0.03$). Total autumn olive branch length was reduced by goat browsing in the mixed grazing treatment by the end of the experiment ($P < 0.02$). Total autumn olive shrub height was not affect by either treatment at the end of the study ($P = 0.33$). Goats grazing with cattle consumed plant species not preferred by cattle. Mixed grazing goats with cattle is a viable option for reclaimed coal-mined lands in Appalachia.

Keywords: Autumn Olive, Browse Species, Cattle, Goat, Grazing, Land Reclamation

Introduction

Mined-land reclamation in the Appalachian coal region of the United States has resulted in successful establishment of pasture for beef-cattle production (Ditsch et al., 2006). However, maintaining desirable pasture species on such sites is difficult due to the low fertility of mine soils and the steep topography (Daniels and Zipper, 2009). As a result, the invasion of undesirable, invasive-plant species is a common occurrence (Wolf et al. 2009).

On reclaimed coal-mined pastures, autumn olive and sericea lespedeza (*Lespedeza cuneata* [Dum.-Cours.] G. Don) are invasive plant species that often reduce pasture production of forage species preferred by cattle. These invasive-plant species are widely adapted with few natural controls, tolerant of poor soil fertility, have physical or chemical deterrents to livestock and wildlife, and compete aggressively with native or more-desirable plant species for nutrients and water (Swearingen et al. 2002; Miller 2003). Sericea lespedeza and autumn olive were commonly used in seed mixtures for coal-mine reclamation (Skousen and Zipper 2009) and may spread in bird droppings (Miller 2003).

Mixed grazing goats with cattle in this region may serve as a viable method of biological control for invasive-plant species. Goats prefer browsing shrub species over grazing grasses and may consume plants with bitter compounds, such as tannins, that are unpalatable by cattle (Luginbuhl et al. 1995). When the two livestock species graze together, competition is minimal, as each species selects their own preferred diet (Walker 1994). In North Carolina, mixed grazing goats with cattle successfully converted brush-infested pasture into desirable, cool-season pasture (Luginbuhl et al. 1999). The objective of this experiment was to investigate the potential effects of mixed grazing goats with cattle versus cattle-alone grazing on forage-standing biomass and forage-botanical composition of pastures infested with invasive-plant species on reclaimed coal-mined lands. The effects of the treatments on autumn olive growth were also investigated.

Materials and Methods

A grazing experiment was conducted during the 2006, 2007, and 2008 growing seasons at the Powell River Project Research and Education Center in Wise County, Va. (77° 43' 30" west longitude, 38° 57' 30" north latitude, elevation 155.5 m). The experimental design was a randomized complete block, with pastures being the experimental unit. The two treatments included cattle-alone grazing and mixed grazing goats with cattle. Three replicate pastures (1.8 ha each) were used for the treatments. Three crossbred steers (280 kg ± 4.0 kg BW SE) were allocated to each grazing treatment. The stocking rate was based on 0.6 ha steer^{-1}. Glimp (1995) suggested that one to three goats could be added to one cow unit without competing for forage resources. The ratio of goats to cattle was higher than that suggestion in this experiment because control and reduction of invasive-plant species was desired (Table 1). The mixed-grazing treatment included 15 young, intact-male, brush-type goats (20.3 kg ± 2.5 kg BW SE) in 2006 and 2007. In 2008, only five young, intact-male goats were used due to a decrease in browse species from previous years' grazing. Animals were grazed on adjacent pastureland for a week prior to the start of the experiment each year. Animals were rotationally stocked among replicates by grazing one replicate for two weeks and then allowing a 4-week rest. Water and trace minerals were provided free choice at all times. Replicates were sampled and animals weighed three times during the growing season (spring, summer, and fall). All weights were unshrunk weights. In 2007, animals were removed from the study for 20 days because of a shortage of forage-standing biomass resulting from dry environmental conditions (Table 1).

Measurements for forage-standing biomass, forage-botanical composition and autumn olive were taken during spring, mid-summer, and late summer or early fall of each grazing season (Table 1). Late-summer and early-fall measurements are designated as "Fall" in the results that follow. Forage-standing biomass was determined by clipping eight 0.25 m^2 quadrants per treatment to a 2.5 cm height from soil level. Samples were dried in a forced-air oven at 105° C for 48 h. Results are presented on a dry-weight basis. Prior to harvesting the forages within each quadrant, the area was visually evaluated by trained evaluators for estimates of percentage ground cover and percent cover by grass, legume, and weed species, with "weed" as a residual category for all species not classified as pasture grasses or pasture legumes, including sericea lespedeza. Sericea lespedeza was classified as a weed in this experiment, due to its lower palatability by cattle (Wolf et al. 2009).

Autumn olive measurements included shrub height, branch length, and shrub survival. Each year, eight shrubs were randomly identified and tagged with a letter in each replicate in the treatments. On each selected shrub, four branches were randomly tagged and numbered from ground level to 3 m. Autumn olive was measured in spring, summer, and fall during each growing season. Branch length was measured with a tape measure in centimeters from

Table 1. Sampling dates for the three experimental years of cattle-alone grazing or mixed grazing goats with cattle on reclaimed pastures in the Appalachian coal region.

	Vegetation sampling dates	Total grazing days	Cattle alone grazing	Mixed grazing
			AUM/ha	
2006	May 30, July 13, and September 29	122	0.9	2.0
2007[a]	May 30, July 13, and August 30	72	0.9	2.0
2008	May 27, July 8, and September 18	114	0.9	1.0[b]

[a] Due to severe drought, animals were removed from treatment paddocks and grazed on adjacent pastures from 13 July to 2 August.
[b] Due to a decrease in autumn olive, the number of goats was reduced in mixed grazing.

the base of the branch to tip at the beginning and end of each sampling period (Oba and Post 1999). Branch length change for the spring-summer period was estimated as the difference between the branch-length measurement at the summer sampling and the initial branch-length measurement at the spring sampling in each treatment. Likewise, the branch length change for the summer-fall period is the difference between the fall sampling and the summer sampling. Total branch-length change was calculated by summing the period changes of spring-summer and summer-fall sampling periods for each year (Oba and Post 1999). Branches that were broken or dead due to goat browsing were recorded. Shrub height was measured with a clinometer at a distance of 10 meters. Shrub-height changes were calculated the same as branch-length change.

Statistical Analysis

Data were analyzed using mixed-model procedures of SAS (SAS Inst. Inc., Cary, N.C.). Forage-standing-biomass and forage-botanical-composition measurements were averaged for each of the sampling seasons (spring, summer, and fall). The model consisted of treatment, season, year, and their interactions. The repeated measure for forage-standing biomass and forage-botanical composition was year x season. Autumn olive data for total branch length and shrub height was averaged to the difference between the spring-summer and summer-fall periods. The model for autumn olive measurements included treatment, period, year and their interactions. The repeated measure for autumn olive measurements was year x period. Significance was declared at $P < 0.05$.

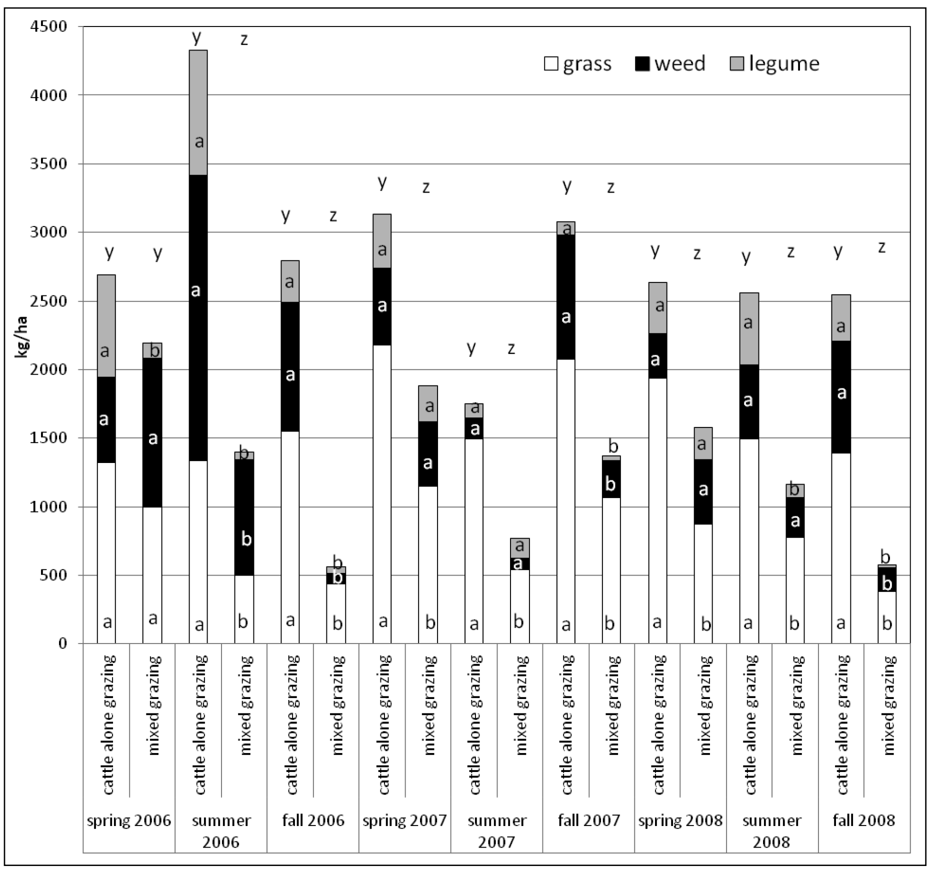
Results and Discussion

Forage Standing Biomass

Forage-standing biomass was influenced by a year x treatment x season interaction ($P < 0.01$). In 2006, forage-standing biomass in the cattle-alone grazing and mixed grazing was similar in spring ($P = 0.06$; Fig. 1). Following the spring of 2006, forage-standing biomass was lower in mixed grazing compared to cattle-alone grazing in all other seasons ($P \leq 0.002$). Goats in mixed grazing readily consumed sericea lespedeza and other weeds. Hart (2001) stated that sericea lespedeza was readily grazed by goats, and invasive stands of sericea lespedeza could be reduced to low levels after three years of grazing. In addition, goats maintained weed species in a vegetative stage of growth that was grazed some by cattle. Sericea lespedeza and other weed species are not tolerant of close and frequent grazing and may be reduced or lost from the stand (Hoveland et al. 1975). Furthermore, most of the weeds, including sericea lespedeza, are tap-rooted species. These species have reduced vigor when grazed late in the growing season due to lower carbohydrate-storage capacity in their roots and may decline from the stand the following year (Hoveland et al. 1975). The combination of goat-diet preferences, greater palatability of re-growth of weed species to cattle, and a slightly higher stocking rate in mixed grazing attributed to lower forage standing biomass in mixed grazing.

In addition, the 2007 and 2008 growing seasons were affected by extreme weather conditions. In 2007, a late frost slowed the emergence of warm-season plant species and a dry summer hindered overall forage-standing biomass. Forage-standing biomass in the treatments was greater in spring and fall, reflecting greater cool-season grass growth in those seasons and the lack of moisture during the summer period (Fig. 1). Summer forage-standing biomass was 42 percent and 61 percent of spring levels in the cattle-alone and mixed-grazing treatments, respectively (Fig, 1). In 2008, another dry year, the average forage-standing biomass from pastures grazed by cattle-alone grazing remained

Figure 1. Seasonal variations in herbaceous biomass (kg/ha) and biomass components for cattle-alone grazing and mixed grazing goats with cattle during three growing seasons on reclaimed pastures in the Appalachian coal region. Letters (y, *z*) above bars illustrate differences in herbaceous biomass within a season (*P* < *0.05*). Differences (a, b) for biomass components compared between treatments are noted within bars for that particular season and year (*P* < 0.05).



fairly constant from spring to fall. However, forage-standing biomass in mixed grazing declined from spring to fall ($P < 0.05$). Drought conditions can be especially stressful to pastures on reclaimed coal-mined lands, as the mine soils typically have low moisture-holding ability (Ditsch et al. 2006). Due to drought conditions in the last two years, animals were removed from paddocks much earlier than the first year (Table 1).

Forage Botanical Composition

The botanical composition of forage-standing biomass was generally impacted by treatment (Fig. 1). In spring 2006, grass ($P = 0.18$) and weed ($P = 0.06$) content of the two treatments were not different but legume content was lower in the mixed-grazing treatment ($P = 0.02$). In summer and fall, grass ($P < 0.001$), weed ($P \leq 0.03$) and legume ($P < 0.001$) content was lower in mixed grazing compared to cattle-alone grazing. Sericea lespedeza and other warm-season weeds made up the large portion of biomass during the summer and fall months. The productive season for these warm-season species is from late May to October (Ball et al. 2007). Goats were observed to consume sericea lespedeza and other weed species readily and helped to reduced forage-standing biomass of these components (Fig. 1) Sericea lespedeza regrowth was multi-branched and leafy, which increased its acceptance by both cattle and goats. Cattle in cattle-alone grazing were observed to only eat the tips of sericea lespedeza and allowed it to become mature and unpalatable.

In 2007, warm-season weeds, such as sericea lespedeza and other species, were not as evident as in the previous year due to a late-spring frost that slowed the growth of these species. Grasses made up the largest fraction of the forage standing biomass for all treatments in spring and summer (Fig. 1). The grass component was lower in mixed grazing compared to cattle-alone grazing in all seasons ($P < 0.001$). Dry conditions during the summer slowed the growth of many species. The tap-rooted, drought-tolerant forbs, such as sericea lespedeza and other warm-season weeds did not make much of an impact on forage-standing biomass until fall. Weed biomass was no different between the treatments in summer ($P = 0.16$). Weed biomass was greater in cattle-alone grazing in the fall compared to mixed grazing ($P = 0.024$). The presence of legumes in forage-standing biomass was similar between treatments in spring ($P = 0.27$) and summer ($P = 0.55$) but lower in mixed grazing in the fall ($P = 0.017$).

In 2008, grass made up a larger portion of forage-standing biomass in cattle-alone grazing compared to mixed grazing during all seasons ($P \leq 0.007$). Similar to 2007, weed content was lower statistically in mixed grazing only during fall compared to cattle-alone grazing ($P = 0.015$). Legumes were similar between the treatments in spring ($P = 0.43$) but lower in mixed grazing in summer ($P = 0.024$) and fall ($P = 0.001$). Legumes were always at a low level during each season as a component of biomass. The drought, acid conditions of reclaimed soils are not favorable for growth of legumes, such as red and white clover (Daniels and Zipper 2009).

The grass components of the pastures were increased at best or maintained in the grazing treatments. The persistence of grasses in the mixed-grazing treatment can in part be attributed to the grazing behavior of goats, which is to graze a sward from top to bottom and thus reduce the shading of grasses and allow tillering (McCall and Lambert 1987). Luginbuhl et al. (2000) showed in North Carolina that grass frequency increased and broadleaf weeds decreased under mixed grazing of goats with cattle. Our experiment showed that grass became a major component of forage-standing biomass in both treatments; however, grass content was lower in mixed grazing compared to cattle-alone grazing after the spring of 2006.

The legume component of the pastures, mainly red and white clover, was not affected by the grazing treatments (Fig. 1). Generally, legumes made of the lowest proportion of forage-standing biomass compared to grass and weed. The only times that legume content was similar between treatments was in the spring and summer of 2007 and in the spring of 2008. In the cattle-alone grazing paddocks, clover was more or less stable during the first growing season but declined by the end of the second grazing season. Cattle tend to select clover over grass when grazing (Ball et al. 2007). Furthermore, the same authors indicated that the reduction in clover content of the cattle pastures can be attributed to shading by grasses and weeds that resulted from spot grazing by cattle (Ball et al. 2007). In the mixed-grazing paddocks, legume content did not make a considerable component of forage-standing biomass.

Autumn Olive

Autumn olive branch length showed treatment x period x year interactions ($P < 0.001$). For 2006, autumn olive branch length was negatively impacted by goat browsing in mixed grazing during the spring-summer period

Table 2. Changes in autumn olive branch length (cm) during three growing seasons on reclaimed pastures in the Appalachian coal region. Columns within season with a different letter differ ($P < 0.05$).

	2006			2007			2008		
Autumn olive	spr-sum	sum-fall	total	spr-sum	sum-fall	total	spr-sum	sum-fall	total
Cattle alone	20.37	1.01^a	21.38^a	4.92	5.05	9.98	13.79	9.08	22.86^a
Mixed	9.47	-5.58^{*b}	3.89^b	0.53	3.76	4.29	9.02	4.05	13.07^b
SE	3.50	1.30	3.63	1.77	2.90	3.08	2.57	2.18	2.86
P-value	0.03	<0.001	<0.001	0.08	0.75	0.19	0.19	0.10	0.02

* Negative number indicates branch length decreased, with the branch unable to grow back during specified season.

Table 3. Changes in autumn olive shrub height (m) during three growing seasons on reclaimed pastures in the Appalachian coal region. Columns within season with a different letter differ ($P < 0.05$).

	2006			2007			2008		
Autumn olive	spr-sum	sum-fall	Total	spr-sum	sum-fall	total	spr-sum	sum-fall	total
Cattle alone	-0.04*	0.23[a]	0.19	0.12	0.28	0.40	0.13	0.14[a]	0.27
Mixed	0.22	-0.14*[b]	0.08	-0.07*	0.47	0.39	0.15	-0.12*[b]	0.03
SE	0.19	0.09	0.19	0.09	0.17	0.13	0.11	0.08	0.11
P-value	0.34	0.005	0.69	0.13	0.44	0.95	0.94	0.02	0.12

* Negative number indicates shrub height decreased, with the shrub unable to regain height during specified season.

($P = 0.03$) and the summer-fall period ($P < 0.001$) (Table 2). Goats were observed to chew the tips of branches if branch tips were slender and tender (Webb 2008). At season's end, the branch-length growth in the mixed grazing treatment was very low compared to cattle-alone grazing ($P < 0.001$). Branch length growth was reduced by 82 percent in mixed-grazing treatment. In 2007, there were no significant differences among treatments at any point during the season ($P = 0.19$). One possible reason for the lack of difference could be that this growing season was drier and autumn olive may go into dormancy during dry periods. However, little research has been conducted on autumn olive to demonstrate this physiological response. In 2008, there was significant difference in total autumn olive branch length ($P = 0.016$) by the end of the grazing season. Any reduction in the growth of autumn olive shrubs by goats can be attributed to the browsing pattern of the goats. When browsing, goats will stand on their hind legs and hold down branches with their weight for easy access to leaves and twigs. When a goat bends down a branch, other goats in the herd may also gather around to browse the branch, thus allowing it to be completely defoliated within a short period. As a result of this browsing behavior, a browse line may develop on shrubs. In our study, we observed an average browse height of 205 cm. This was higher than the 150 cm reported for free-ranging goats browsing *Acacia tortilis* in Kenya (Oba and Post 1999). Browsing height is likely influenced by the size of the goat. Branches were broken and killed at times, as branches became brittle from excessive browsing. As forage became limiting at the end of the growing season, goats began to strip bark from shrubs. Bark stripping can girdle and kill shrubs. This is similar to findings from New Zealand, where goats were observed to strip bark from gorse (*Ulex europaeus*) and eventually eliminate this leguminous shrub in four years of heavy browsing (Field and Daly 1990). Another cause for autumn olive loss may be that browsing the shrubs late in the growing season can cause a reduction in energy storage in the roots needed for winter survival. Loescher et al. (1990) stated that late summer and autumn pruning of fruit or timber tree species resulted in decreased carbohydrate storage in the roots and lower production the following year.

Autumn olive shrub height showed a weak treatment x period x year effect ($P = 0.057$). In 2006, there were no differences during the spring-summer period among treatments (Table 3) but during the summer-fall period, the mixed-grazing-height change was significantly lower ($P = 0.005$). In 2007, autumn olive height was not significantly affected by any treatment ($P = 0.95$). In 2008, spring-summer period was not affected by goat browsing but summer-fall period was affected ($P = 0.02$). Generally, mixed grazing did not have influence on autumn olive height compared to cattle-along grazing by end of the grazing season of each of the experimental years ($P = 0.33$). This is in agreement with the findings of Oba and Post (1999) of browsing of *Acacia tortilis* by goats in Kenya.

Despite persistent browsing by goats in the mixed-grazing treatment, autumn olive illustrated a degree of resiliency. After hard browsing and branch death, the shrub would occasionally produce numerous suckers from the base of the plant. This lush growth lacked thorns or physical deterrents. This growth was highly preferred and accessible to goats. Cattle would occasionally browse this growth if it was accessible. Luginbuhl et al. (2000) observed that cattle would browse black locust (*Robina pseudoacacia*) and that when given opportunity cattle would browse and become opportunistic browsers. Another observation of the resiliency of autumn olive was that when allowed a rest period of four to six weeks, due to rotational grazing pattern, leaves would regrow to the size prior to browsing. In a long-term study, Carmel and Kadmon (1999) found that the grazing of goats and cattle slowed the establishment and growth of woody vegetation but did not halt the succession of rough topography pasturelands to woody vegetation in the Mediterranean region in Israel. If not an exotic invasive species of high concern, the high protein and feed value (data not shown) of autumn olive would warrant it to be managed as a possible continual forage source for goats (Webb 2008). Additionally, with autumn olive being a non-leguminous, nitrogen fixer, it could possibly improve nitrogen cycling on reclaimed coal-mined areas. A similar suggestion (maintenance of invasive-browse species in pastures) was presented for gorse- (another nitrogen fixing shrub) infested pastures in New Zealand but has not met wide-spread acceptance with producers (Field and Daly 1990).

Conclusions

Goats can complement cattle on botanically diverse pastures on reclaimed coal-mined lands in the Appalachian region. Research has indicated that one to three goats can be added per cow unit without competing for forage resources. In this experiment, the goal was to reduce invasive-plant species quickly, and this can be accomplished with an increased ratio of goats to cattle. The presence of weeds was reduced in mixed grazing compared to cattle-alone grazing. The change in forage-botanical composition due to grazing can be attributed to the grazing pattern and diet preference of the grazing animals. Goats and cattle differ in their grazing behaviors and diet preferences. Goats showed a clear preference for browse species and warm-season weeds. Goat browsing had a negative impact on autumn olive branch length. Reducing autumn olive as a pasture component can benefit cattle by allowing other desirable pasture species an opportunity to compete for sunlight and nutrients. Mixed grazing goats with cattle is a viable practice on reclaimed coal-mined lands, where there is a diversity of plant species found in pasture.

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