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*E*ffects of Concentrate Level and Pen Configuration on Performance of Boer Crossbred Goat Kids

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ABSTRACT

One hundred eighty-one Boer-sired goat kids from dams of predominantly Spanish breeding (17.6 ± 2.34 kg initial BW; 177 wethers, 4 doelings) were used to determine optimum inclusion level of concentrate in diets fed to goats in confinement. Effects of elevated loafing areas on performance were also examined. Goats were blocked by weight (2 blocks per treatment) and randomly assigned to 1 of 12 outdoor pens (4.3 m²; 15 to 16 head/pen) with concrete floors. Pens of goats were randomly assigned, within block, to 1 of 6 treatments. A 2 × 3 factorial arrangement was used with factors consisting of pen configuration, defined as the presence or absence of a concrete structure (45 cm high, 75 cm wide, and 150 cm long) in the center of the pen, and level of concentrate in the diet (50, 70, or 90%). Goats were fed diets ad libitum twice daily for 126 d. Dry matter intake decreased linearly (P < 0.01) and gain efficiency increased linearly (P = 0.03) as the proportion of concentrate in the diet increased. Average daily gain

(P < 0.01) and final BW (P = 0.02) responded quadratically to concentrate level, and were greatest for goats fed 70% concentrate. Presence of an elevated loafing area in the pen tended to decrease DMI (P = 0.09). Increasing the level of concentrate in the diet generally improved performance of Boer-crossbred goat kids fed in confinement.

Key words: goat, concentrate level, behavior

INTRODUCTION

The utility of goats in managing undesirable vegetation has been well established. Many studies have demonstrated the ability of goats to substantially decrease brush species in infested pastures while significantly increasing vegetative growth of favorable grass and legume species, thereby increasing the carrying capacity of pastures for other species of livestock (Townsend and Radcliffe, 1990; Essam Dabaan et al., 1997; Luginbuhl et al., 1998). In this function goats serve as a favorable alternative to herbicide application, which can pose both environmental and public perception concerns. Production efficiency in these systems, however, can be compromised.

Undersupply of goat meat in the United States has created an economic climate that favors increases in domestic production. Since 1994, the United States has been a net importer of goat meat, and in 2003 imports of goat meat reached 19 million pounds at a total value of $21.48 million (Singh-Knights and Knights, 2005). Demand for goat meat in the United States is largely derived from consumption by various ethnic and religious groups. Recent population shifts have caused consumption of goat meat in the United States to rise more rapidly than that of any other meat. Because consumption of goat meat is tied to cultural practices, demand appears to be relatively inelastic (Singh-Knights and Knights, 2005). Although increasing numbers of meat goats is a logical solution to address the deficit in supply of goat meat in the United States, introduction of concentrate feeding also can increase supply of marketable product. Compared with other livestock species, relatively few studies have examined the use of high-concentrate diets for goat production and their impact on sensory attributes of goat meat. Moreover, observations of the effects of animal behavior and social hierarchy on production of meat goats

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are rare. This study was conducted to evaluate the effects of varying proportions of roughage and concentrate in the diet and the addition of elevated loafing areas on performance of Boer-crossbred goat kids fed in confinement. A companion experiment examining the prevalence of *Escherichia coli* O157 in goats used in this study has been previously published (Fox et al., 2007). Additionally, a study has been previously published that compares the sensory traits of meat derived from a subsample of goats used in this study and goats consuming a browse-based diet (Ryan et al., 2007).

MATERIALS AND METHODS

Animals and Experimental Design

Procedures for this study were approved by the Kansas State University Institutional Animal Care and Use Committee. One hundred eighty-one Boer-sired goat kids from dams that were of predominantly Spanish

breeding (17.6 ± 2.34 kg initial BW; 177 wethers, 4 doelings) were transported (approximately 240 km) to the Kansas State University Beef Cattle Research Center in Manhattan, Kansas, from pastures near Buffalo, Kansas. Within 24 h after arrival, each goat was individually identified with an ear tag and a BW was recorded. Goats were blocked by weight (heavy and light) and randomly assigned to 1 of 12 concrete-surfaced, outdoor pens (4.3 m^2; 15 to 16 animals/pen) that were equipped with feed bunks and automatic waterers that were fashioned using a bucket with a float attached to the water shut-off valve. A randomized complete block design with a 2 × 3 factorial arrangement was utilized. Factors consisted of pen configuration, defined as the presence or absence of an elevated loafing area (45 cm high, 75 cm wide, 150 cm long) in the pen, and 3 levels of concentrate in the diet (50, 70, or 90%; DM basis; Table 1). A series of transition diets (50, 60, 70, 80, and 90% concentrate) were used to adapt goats to the greater concentrate levels. Con-

sequently, goats fed 70% concentrate were introduced to their final diet by d 13, and goats fed 90% concentrate began receiving their final diet on d 22. Safeguard Goat Dewormer (Intervet, Millsboro, DE) was administered orally at a rate of 2 mL/goat on d 49 and 105. The elevated dose was used per the instructions of our animal veterinarian.

Diets were fed for 126 d as a TMR twice daily in amounts that were sufficient to not limit feed intake while minimizing waste. Weekly feed refusals were weighed back and DM content was determined using a 55°C oven. The alfalfa hay used in this study was purchased from a local farmer. The hay had been chopped through a 7.5-cm screen and the approximate particle size was between 4 and 7 cm. On d 113, diets were reformulated to include 1% salt and 0.5% ammonium chloride to address problems with urolithiasis.

Removal of goats due to urolithiasis occurred on d 82, 85, 87 (2 goats), 108, 109, 116, 117, 120, and 121 of the study. Upon initial appearance of clinical signs of urolithiasis, goats were examined by a veterinarian. If appropriate, the urethral process of those goats was surgically amputated by a veterinarian. Goats that continued to exhibit signs of or experienced a reoccurrence of urolithiasis were removed from the study and killed. Following death or euthanasia of a goat for any reason, the animal was transported to the Kansas State University College of Veterinary Medicine Diagnostic Laboratory where a post-mortem examination was performed to determine the cause of death or symptoms warranting euthanasia.

Statistical Analysis

Performance data were analyzed using the mixed procedure of SAS (Littell et al., 1996). Factors included in the model were concentrate level, pen configuration, and the interaction between concentrate level and pen configuration. The random variable was weight block. Orthogonal contrasts were used to detect linear

Table 1. Composition of diets fed for 126 d to Boer-crossbred goat kids housed in pens with or without an elevated loafing area (% of DM)[1]

Item	Concentrate level, % of dietary DM		
	50	**70**	**90**
Ingredient			
Dry-rolled corn	42.5	60.6	78.5
Alfalfa hay	49.8	29.8	9.9
Corn steep liquor	7	7	7
Soybean meal	0	1	2
Limestone	0.12	0.74	1.39
Salt	0.3	0.3	0.3
Urea	0.16	0.43	0.76
Potassium chloride	0	0.01	0.03
Vitamin-mineral premix[2]	0.12	0.12	0.12
Nutrient analysis			
CP, %	18.1	17.0	16.0
Ca	0.95	0.84	0.73
P	0.36	0.38	0.40
Ca:P	2.64	2.21	1.83

[1]On d 113, diets were reformulated to include 1% salt and 0.5% ammonium chloride. These changes were made to address problems with urolithiasis.

[2]Formulated to provide 0.1 mg/kg of Co, 8 mg/kg of Cu, 0.5 mg/kg of I, 50 mg/kg of Mn, 0.3 mg/kg of Se, 50 mg/kg of Zn, 2,595 IU/kg of vitamin A, 22 IU/kg of vitamin E, and 17 mg/d of monensin per goat.

Table 2. Causes of death or euthanasia of Boer-crossbred goat kids fed diets containing 50, 70, or 90% concentrate and housed in pens with or without an elevated loafing area[1,2]

Cause of death or euthanasia	Concentrate level			P-value[3]
	50	70	90	
Urolithiasis (water belly)	2	7	1	0.07
Respiratory	0	1	1	0.55
Gastrointestinal parasites	0	0	3	0.07
Urinary tract infection	1	0	0	1.00
Digestive	0	0	1	0.66
Total	3	8	6	0.26

[1]Cause of death determined by the Kansas State University Veterinary Medicine Diagnostic Laboratory.

[2]No effect of loafing area on mortality rates was observed ($P \geq 0.54$).

[3]Fisher's exact test.

and quadratic effects of concentrate level. No interactions between concentrate level and pen configuration were observed; thus only main effects are reported. Performance data were analyzed with dead animals excluded from the analysis and also with data from the dead animals included in the analysis. Final BW and ADG were assumed to be zero for goats that died or were killed when data from them were included in the analysis. On the day that goats that died were not in the pen, DMI was considered zero for those goats when calculating per head daily DMI. Data for goat mortalities were analyzed using Fisher's exact test in the PROC FREQ procedure of SAS.

RESULTS AND DISCUSSION

Health Data

Seventeen goats died or were killed (Table 2); 10 deaths were due to urolithiasis. Death loss of 9% was greater than expected, although only a 3% death loss was incurred for causes other than urolithiasis. Seven of the 10 goats that died from urolithiasis were fed the 70% concentrate diet and all 3 of the goats that died from gastrointestinal tract parasites were fed the 90% concentrate diet. There was a tendency for diet to effect the number of mortalities caused by urolithiasis and gastrointestinal tract parasites ($P = 0.07$ for both), but diet did not affect any other causes of death ($P > 0.26$). Of the 7 goats that died from causes other than urolithiasis and gastrointestinal parasites, 2 were due to respiratory disease, one was due to infection of the urinary tract, and one was due to digestive problems. No effect of pen configuration on causes of mortality was observed ($P > 0.54$).

Reasons for the observation of a potential dietary effect on deaths caused by gastrointestinal tract parasites are unclear. Furthermore, the impact that possible subclinical internal parasite infestation in all treatment groups may have had on performance cannot be determined. Removal of goats from the study for complications due to gastrointestinal tract parasite infestation occurred on d 9, 82, and 117 of the study, and may indicate parasitic resistance to the anthelmintic used (Zajac and Gipson, 2000).

An analysis that included data from goats that had died or were killed was included primarily to demonstrate the variable effects that concentrate level in the diet appeared to have on urolithiasis. Goats have a propensity to sort feedstuffs, so in future experiments it would be useful to pellet diets fed to goats to ensure that the observed effects are due consumption

of the total diet and not a result of sorting. The high incidence of urolithiasis in this study supports the observations made by Sato and Omori (1977) that goats are susceptible when fed diets high in phosphorus. Based on our subjective observations it appeared that goats fed the 70% concentrate diet were more inclined to sort their feed, consuming primarily concentrate. This observation is supported by the greater incidence of urolithiasis in goats fed the 70% concentrate diet (11.7%) compared with urolithiasis incidence observed in those fed the 50% (3.3%) or 90% (1.7%) diets. Moreover, the analyzed Ca:P ratios of the mixed diets (2.64, 2.21, and 1.83 for the 50, 70, and 90% concentrate diets, respectively; Table 1) were greater than the recommended Ca:P ratio of 1.5 (NRC 1981), indicating that sorting played a role in urolithiasis incidence. Because of the relatively high concentration of Ca in alfalfa hay (1.77% DM for the alfalfa hay used in this study), failure to consume alfalfa hay at a rate proportional to concentrate in the diet potentially caused the Ca:P ratio consumed to be less than recommended levels. Goetsch et al. (2003) allowed Alpine doelings ad libitum access to a concentrate mix (72.8% ground corn, 15.2% soybean meal, 6% fish meal, and 6% dried molasses) and wheat hay offered separately and found that voluntary intake of the concentrate mix and wheat hay was 83.6 and 16.4% of diet DM, respectively. Goats fed the 70% concentrate diets in this study may have exhibited similar concentrate and forage intake patterns. The lesser incidence of urolithiasis in goats fed the 50% concentrate diet compared with goats fed the 70% concentrate diet may have been a consequence of limited access to concentrate with the 50% concentrate diet increasing intake of alfalfa hay. Additionally, the lesser incidence of urolithiasis in goats fed the 90% concentrate diet compared with goats fed the 70% concentrate diet was likely the result of limestone supplying a greater proportion of dietary Ca (Table 1), and the presumed

Table 3. Performance and carcass characteristics of Boer crossbred goat kids fed diets containing 50, 70, or 90% concentrate and housed in pens with or without an elevated loafing area (animals that died during the study not included in analysis)

	Concentrate level (%)				Pen configuration			Concentrate level P-value	
Item	50	70	90	SEM	Flat	Elevated loafing area	SEM	Linear	Quadratic
Number of head[1]	58	52	54	—	82	82	—	—	—
Initial BW, kg	17.58	17.44	17.59	2.34	17.49	17.59	2.34	0.97	0.45
Final BW, kg	29.79	30.39	28.91	2.23	29.51	29.89	2.22	0.05	0.02
Daily gain, g	97	103	90	2	95	98	1	0.04	<0.01
DMI,[2] g/d	923	830	735	45	848	811	44	<0.01	0.97
G:F	0.1054	0.1241	0.1232	0.0081	0.1136	0.1216	0.0077	0.03	0.11

[1]Seventeen goats died or were killed during the study.

[2]Effect of pen configuration, $P < 0.09$.

inability of goats to sort limestone out of the diet. Therefore, Ca source particle size is a potentially important in finishing goat diets, although this may be less of a concern in diets containing lesser ($\leq$50% of DM) amounts of concentrate.

Effects of Concentrate Level

Performance data with dead goats excluded are shown in Table 3. There were quadratic effects of concentrate level on final BW ($P = 0.02$) and daily gain ($P < 0.01$), with goats fed the 70% concentrate level having the greatest value for both variables and goats fed the 90% concentrate having the lowest value for both variables. Dry matter intake decreased linearly ($P < 0.01$) as level of concentrate in the diet increased, and gain efficiency improved linearly ($P = 0.03$) as level of concentrate in the diet increased.

Performance data including data from the 17 goats that died or were killed are presented in Table 4. When data from these goats were included in the analysis, there was a linear decrease ($P < 0.01$) in DMI as level of concentrate in the diet increased, but no other performance variables were affected by treatment ($P \geq 0.13$). However, the numerically greatest gains were observed in goats fed the 50% concentrate diet when data from all goats were included in the analysis.

When interpreting the results from this study, the possibility that subclinical urolithiasis may have affected performance must be recognized.

Goats fed the 70% concentrate diet would have been expected to be the most afflicted, as they exhibited the greatest symptoms of clinical urolithiasis. However, as mentioned above, daily gains responded quadratically ($P < 0.01$) for the goats that remained on the study for the entire 126 d, with goats fed the 70% concentrate diet having the greatest daily gains. When data from goats that died are excluded, results from this experiment are similar to those of other experiments using increasing levels of concentrate in goat diets. Goetsch et al. (2003) observed that daily gain and G:F increased in Alpine doelings (fed 25, 50, or 75% concentrate) as level of concentrate in the diet increased. The authors reported that there were no statistical differences in

Table 4. Performance of Boer crossbred goat kids fed diets containing 50, 70, or 90% concentrate and housed in pens with or without an elevated loafing area (animals that died during the study included in analysis)

	Concentrate level (%)				Pen configuration			Concentrate level P-value	
Item	50	70	90	SEM	Flat	Elevated loafing area	SEM	Linear	Quadratic
Number of head	61	60	60	—	91	90	—	—	—
Final head count	58	52	54	—	82	82	—	—	—
Initial BW, kg	17.65	17.46	17.65	2.33	17.60	17.57	2.33	0.98	0.13
Final BW, kg	28.40	26.51	26.18	3.55	27.05	27.01	3.50	0.17	0.54
Daily gain, g	85	72	68	11	75	75	10	0.16	0.63
DMI, g/d	904	813	705	59	830	785	58	<0.01	0.73
G:F	0.0944	0.0888	0.0953	0.0095	0.0891	0.0961	0.0077	0.95	0.58

DMI, but numerically DMI was highest in goats consuming a 50% concentrate diet and lowest in goats consuming a 25 and 75% concentrate diet. Urge et al. (2004) reported increased ADG and G:F in goats fed diets containing 75% concentrate compared with goats fed a diet containing 50% concentrate during the initial 12 wk of the feeding trial, with DMI being less for goats fed 75% compared with 50% concentrate.

Effects of Pen Configuration

There were no effects of pen configuration on final BW, ADG, or G:F ($P > 0.10$), but there was a tendency ($P = 0.09$) for DMI to be less in pens containing elevated loafing areas when data from goats that died were not included in the analysis (Table 3). All variables measured were similar between pen configurations when data from goats that died during the study were included in the analysis ($P \geq 0.13$). Less DMI in pens that contained an elevated loafing area can potentially be explained on the basis that submissive animals sought refuge on the loafing area to avoid confrontation with socially dominant goats in the pen. This may have led to less frequent or shorter duration visits to the feed bunk for less aggressive goats. Barroso et al. (2000) demonstrated a linear hierarchical order in goat herds that influenced consumption of shrubs and forbs as well as production in goats allowed to graze during the day. Constant confinement of goats in this study may have exaggerated social stressors, thereby affecting eating behaviors. The observation of reduced intake coupled with similar ADG may indicate that concrete blocks removed some of the stress associated with social behavior of goats. Changes in eating behaviors in response to social stress in pigs have been described (Bornett et al., 2000; Hyun et al., 1998) and may provide

some insight into observations in this study. Conversely, the loafing areas may have occupied goats and led to a reduction in feed wastage, as goats had a tendency to climb on and stand in the feed bunk.

IMPLICATIONS

Results from this study indicated an effect of concentrate level on incidence of urolithiasis in goats fed alfalfa hay as the roughage source. Therefore, eating behavior of goats should be considered when formulating diets and appropriate preventive measures are recommended. Data from goats that remained on the study for the entire 126-d period indicated that final BW and ADG respond quadratically to proportion of concentrate in diets with alfalfa hay as the roughage source. However, gain efficiency improved linearly with increasing concentrate level in those goats. Finally, the presence of an elevated loafing area tended to reduce DMI, possibly indicating an effect of behavior on eating patterns in goats. Results from this study indicate an effect of diet on incidence of urolithiasis in goats fed alfalfa hay as the roughage source. This was apparently due to sorting of the roughage and concentrate at the intermediate concentrate level, and proper dietary measures need to be taken to address potential urolithiasis problems.

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