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Effects of feed restriction and realimentation on mohair fiber growth and tissue gain by growing Angora goats

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ABSTRACT

Angora wethers (48), approximately 6 months of age and 15.7 kg initial BW (SEM = 0.38), were used to determine the effects of the level of feed intake and realimentation on mohair fiber growth and tissue gain. There were two 12 weeks phases in which dehydrated alfalfa pellets (18% CP and 48% NDF, DM basis) were fed. In phase 1, feed amounts were intended to provide ME adequate for 0, 15, 30, 45, 60, and 75 g/day of tissue (non-fiber) gain and 0, 1.5, 3.0, 4.5, 6.0, and 7.5 g/day of clean mohair fiber growth, respectively (L1, L2, L3, L4, L5, and L6, respectively), although actual levels were slightly greater; intake was ad libitum in phase 2. DM intake in both phases increased linearly ($P<0.05$) with increasing level of feed offered from 0.48 to 1.00 kg/day in phase 1 and 1.08 to 1.48 kg/day in phase 2. Tissue gain increased linearly ($P<005$) with increasing level of feed offered in phase 1 from 15.3 to 72.1 g/day and decreased slightly in phase 2 from 105.6 to 97.0 g/day. Greasy mohair fiber growth was not affected by treatment in phase 1 (6.31, 6.18, 6.85, 7.14, 7.07, and 6.47 g/day; SEM = 0.431) or 2 (6.59, 6.67, 6.52, 7.21, 7.69, and 6.64 g/day for L1, L2, L3, L4, L5, and L6, respectively; SEM = 0.349). During the entire experiment, mohair fiber growth relative to DM intake decreased linearly ($P<0.05$) from 8.40 to 5.37 g/kg with increasing level of feeding in phase 1. Mohair fiber diameter increased linearly ($P<0.05$) from 22.4 to 23.8 μm in phase 1 and 25.4 to 27.1 μm in phase 2. Digestibility of DM components and energy utilization were determined once per phase. Digestibility of OM was similar among treatments in phase 1, whereas values in phase 2 increased linearly ($P<0.05$) from 68.0 to 73.4% as the level of feed offered in phase 1 increased. Assuming the requirements of 37.2 and 157 kJ/g of tissue and clean mohair fiber gain, ME used for maintenance (ME_m) in phase 1 was not affected by treatment. In phase 2, ME_m was greater than in phase 1 (mean = 431 kJ/kg $BW^{0.75}$) and increased linearly ($P<0.05$) as the level of feed offered in phase 1 increased (551, 599, 647, 765, 788, and 902 kJ/kg $BW^{0.75}$ for L1, L2, L3, L4, L5, and L6, respectively; SEM = 97.5). The phase difference and unrealistically high values for some treatments may have resulted from a greater requirement than assumed for tissue gain in phase 2. This may have been because levels of fat and energy in tissue gained was greater in phase 2 than 1 and increased in phase 2 as the level of feed offered in phase 1 increased. In summary, with levels of intake above maintenance, growing Angora goats partition nutrients to mohair fiber growth at the expense of tissue gain. Realimentation likewise does not affect mohair fiber growth but can increase tissue gain, the magnitude of which depends on the severity of previous intake restriction.

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1. Introduction

Nutrition plays an important role in determining the quality and quantity of wool and mohair produced. Animals producing high amounts of fiber have a high metabolic priority for fiber growth relative to use by other peripheral tissues. However, the

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extent of preferential partitioning of nutrients by Angora goats to fiber production with moderate degrees of nutrient restriction, as well as impacts of periods of nutrient restriction on subsequent tissue and fiber accretion during realimentation, have not been thoroughly described. In many rangeland situations, moderate degrees of under-nutrition of grazing animals including goats are common during parts of the year because of limited rainfall and seasonal changes that impact forage growth and quality. Supplementation strategies can be employed to maintain adequate nutrient intake, but with monetary input (Huston et al., 1993). However, it may be possible to allow reduced performance during some feed-deficit periods if overall, long-term productivity is not impaired.

Partitioning of nutrients for various physiological processes such as tissue (non-fiber) gain, mohair growth, pregnancy, and lactation is coordinated by hormones. For instance, during lactation fiber growth is reduced to sustain milk production (Langlands, 1977; Thornton, 1987; Sahlu et al., 1999a) due in part to an elevated level of prolactin that contributes to preferential nutrient flow to the mammary gland (Puchala et al., 2003). Effects of this partitioning on fiber growth would be expected to be relatively greater with high vs. low degrees of nutrient restriction. There is also competition for nutrients in non-lactating Angoras between mohair fiber growth and use for maintenance and possible accretion of other non-fiber tissues. In this regard, Sahlu et al. (1999b) investigated different levels of feed DM intake by 14-month old Angora goats for 40 days and subsequent ad libitum consumption for 41 days on body weight (BW) change and mohair growth rate. Nutrient restriction reduced mohair growth, but had a relatively greater effect on change in weight of non-fiber tissues. In the subsequent feeding period, mohair growth continued to decrease linearly with increasing previous level of feed intake, but growth by non-fiber tissues was completely compensatory. These results cannot necessarily be directly extrapolated to younger, growing Angoras, which would have greater nutrient demands for growth of non-fiber tissues and possibly less tissue stores for mobilization to support mohair fiber growth.

Recently, NRC (2007) recommended energy and protein requirements for Angora goats determined by Luo et al. (2004). However, these requirements were derived from databases of treatment means from the literature primarily involving studies without nutrient restriction. Thus, their applicability to Angoras on limited nutritional planes is unknown. For example, goats (Sahlu et al., 2004) as well as other ruminant species (SCA, 1990; NRC, 2000, 2007) can reduce heat production when energy intake is restricted, but the capacity of Angora goats to do so has not been extensively studied. Hence, this experiment was conducted to determine the effects of different levels of feeding on nutrient partitioning to mohair fiber growth and tissue gain by growing Angora goats, as well as effects on subsequent partitioning with a high nutritional plane.

2. Materials and methods

2.1. Animals, diets, and treatments

Forty-eight Angora wethers (15.7 ± 0.38 kg initial BW and 6 months of age) were used. Wethers had been weaned at 4.5 months of age. The experiment lasted 24 weeks, consisting of two 12 weeks phases and three 4 weeks periods in each phase. Goats were subjected to standard management procedures of the American Institute for Goat Research (AIGR) of Langston University, such as vaccination for enterotoxaemia and treatment for internal and external parasites. Goats were acclimatized to the experimental diet and individual elevated pens (1.1 × 0.9 m) for 5 weeks prior the commencement of the experiment.

In the first phase, wethers were fed dehydrated alfalfa pellets at six levels, with eight animals per treatment, and had free access to drinking water. Animals were randomly allocated to treatments. On a DM basis, alfalfa pellets averaged 17.8% crude protein (CP), 47.8% neutral detergent fiber (NDF), 37.4% acid detergent fiber (ADF), and 11.8% ash. Feeding levels of alfalfa pellets were intended to provide ME adequate for 0, 15, 30, 45, 60, and 75 g/day of tissue (i.e., non-fiber) gain and 0, 1.5, 3.0, 4.5, 6.0, and 7.5 g/day of mohair fiber growth, respectively (L1, L2, L3, L4, L5, and L6, respectively). Amounts of pellets offered were based on the goat nutrient requirement calculation system of the AIGR (available at www2.luresext.edu), which applies recommendations of NRC (2007) from Luo et al. (2004), and an assumed ME concentration of 9.2 MJ/kg DM. It was first planned to have set amounts of pellets fed throughout phase 1 based on initial BW plus 1.7 kg as a projection of average BW gain during the first 6 weeks. However, amounts were inadvertently adjusted after each 4 weeks period, with each estimation including the addition of 1.7 kg BW. Hence, actual quantities of feed offered in phase 1 were greater than first planned. In Phase 2, all animals were offered alfalfa pellets at approximately 110% of consumption on the preceding few days for ad libitum intake. A mixed supplement of dicalcium phosphate (15%), vitamin premix (25%), trace mineralized salt (25%), and dried molasses product (35%) was top-dressed at 0.05% of BW throughout the experiment. Alfalfa pellets and the mineral supplement were offered in two equal meals at approximately 09:00 h, following collection, weighing, and discarding of orts, and at 15:00 h.

2.2. Measurements and samples

The whole body was shorn before the start of the experiment, and mohair was clipped from a defined mid-side area of skin (10 × 15 cm) that was collected separately. At 2 weeks after the start of the experiment as well as after each 4 weeks period, mohair fiber was harvested from the same mid-side patch area. The average ratio of mohair fiber of the mid-side patch to that of the whole body determined before the experiment was used to estimate daily whole body mohair fiber growth during the periods. Tissue gain was determined as the difference between average daily BW gain (ADG) and daily mohair fiber growth. The mid-side patch mohair samples were used to determine clean yield and medullation (ASTM, 1988), while fiber diameter was determined with a Peyer FDA 200 system (Peyer, Wallerau, Switzerland). BW of all wethers was determined at the beginning of the experiment, at the end of each 4 weeks period, and before and after determination of digestibility.

Thirty-six of the 48 wethers (six per treatment) were used to evaluate digestibility and metabolizability. Wethers were placed into three sets, with 12 per set, consisting of two wethers per treatment. Total collections of feces and urine were performed over a 6-day period in weeks 6–8 while in metabolism crates. Feces were collected in wire-screen baskets placed under the floor of the crates, and urine was collected through a funnel into plastic buckets containing 20 ml of a 10% (vol/vol) solution of sulfuric acid. After weighing, aliquots (10%) of daily excretion of urine and feces were sampled to make composite samples for each animal and phase, which were stored at −20 °C until analyses. Feed samples were collected daily for formation of weekly composites. Partial DM concentration in feed and feces was determined by oven-drying at 55 °C. Thereafter, samples were ground to pass a 1-mm screen before analysis for DM (100 °C), ash, Kjeldahl N, gross energy (GE) using an adiabatic oxygen bomb calorimeter (Parr Instrument Co., Moline, IL) (AOAC, 1990), NDF, and ADF (filter bag technique; Ankom Technology Corp., Fairport, NY). Urine samples were freeze-dried and analyzed for DM and GE.

2.3. Calculation and statistical analyses

Intake of ME (MEI) was calculated as the difference between GE intake during the week of digestibility measurement and the sum of GE of feces, urine, and CH_4. A CH_4 emission loss of 3.5% of GE intake was assumed based on findings of Tovar-Luna et al. (2007a,b) with coarsely chopped alfalfa hay diets. The quantity of ME used for maintenance (ME_m) was estimated as the difference between MEI and that used for tissue gain and clean mohair fiber growth assuming the requirements of 37.2 and 157 kJ/g, respectively (Luo et al., 2004; NRC, 2007). Tissue gain and clean mohair fiber growth values used in calculations were averages of the three 4 weeks periods within phases. The BW assumed for expressions relative to $BW^{0.75}$ was that determined during the week of estimating digestibility.

Measures determined in the three 4 weeks periods within each phase were analyzed by SAS (1990) using mixed model procedures (Littell et al., 1996), with a model consisting of treatment, period, and their interaction; period was a repeated measure and animal within treatment was a random effect. The only significant interactions between treatment and period within phase were for BW; therefore, some means were averaged across periods within phase. Digestibility and energy data were analyzed by phase with the general linear model (GLM) procedure of SAS and a model consisting of treatment. Orthogonal contrasts were employed for linear and quadratic effects; however, no quadratic effect was significant ($P>0.05$).

3. Results

3.1. DM intake, BW, and tissue and mohair fiber growth

As expected, DM intake in phase 1 increased linearly ($P<0.05$) with increasing level of offered feed (Table 1). BW at the end of phase 1 and tissue (non-fiber) gain increased linearly ($P<0.05$) with increasing level of offered feed. Tissue gain was lower in period 2 than in period 1 ($P<0.05$), with an intermediate value ($P>0.05$) for period 3. The ratio of ADG (i.e., tissue gain plus mohair fiber growth) to DM intake was similar among treatments ($P>0.05$) and lowest ($P<0.05$) for

Table 1
Effects of the level of feed intake on BW, DM intake, tissue gain, and mohair fiber growth and characteristics of Angora wethers.

Item	Treatment [1]						SEM	Linear P value [3]	Period [2]			SEM
	L1	L2	L3	L4	L5	L6			1	2	3	
Phase 1 [4]												
DM intake (kg/day)	0.48	0.58	0.66	0.77	0.88	1.00	0.019	0.0001	0.71^a	0.73^{ab}	0.74^b	0.008
BW (kg)	16.9	17.3	17.7	19.0	20.3	22.6	0.93	0.0001	17.9^a	18.5^b	20.3^c	0.38
ADG:DM intake (g/kg)	45	65	84	85	80	79	15.9	0.1037	104^b	36^a	80^b	11.2
Tissue gain (g/day)	15.3	30.9	49.2	58.9	62.5	72.1	9.32	0.0001	70.8^b	17.6^a	56.1^{ab}	6.59
Mohair fiber												
Growth (g/m^2 in 28 days)	341	333	369	385	381	349	23.4	0.3001	367	370	343	11.9
Growth (g/day)	6.31	6.18	6.85	7.14	7.07	6.47	0.431	0.3001	6.80	6.85	6.36	0.221
Yield (%)	78.0	76.4	76.9	79.0	80.7	76.8	1.57	0.3530	74.7^a	78.0^b	81.1^c	0.760
Diameter (µm)	22.4	22.4	22.9	23.9	24.5	23.8	0.66	0.0118	22.2^a	23.9^b	23.8^b	0.29
Medullation (%)	0.96	0.70	0.80	0.71	0.92	1.36	0.235	0.1885	0.90	1.05	0.79	0.114
Phase 2												
DM intake (kg/day)	1.08	1.12	1.16	1.24	1.28	1.48	0.062	0.0001	1.07^a	1.27^b	1.33^b	0.027
BW (kg)	24.5	24.9	24.0	26.5	27.8	30.4	1.17	0.0001	24.0^a	26.9^b	28.1^c	0.58
ADG:DM intake (g/kg)	106	107	87	72	71	72	8.6	0.0001	110^c	90^b	57^a	5.2
Tissue gain (g/day)	105.6	108.3	91.9	81.9	76.0	97.0	8.19	0.0326	125.4^c	97.9^b	57.1^a	5.85
Mohair fiber												
Growth (g/m^2 in 28 days)	356	360	352	389	415	359	18.7	0.1803	315^a	383^b	417^c	8.83
Growth (g/day)	6.59	6.67	6.52	7.21	7.69	6.64	0.349	0.1803	5.83^a	7.10^b	7.71^c	0.164
Yield (%)	87.9	88.0	88.6	88.4	88.1	86.5	1.33	0.3458	91.0^c	88.0^b	83.9^a	0.67
Diameter (µm)	25.4	25.5	26.0	27.1	27.0	27.1	0.71	0.0243	24.8^a	26.2^b	28.0^c	0.35
Medullation (%)	1.21	1.19	1.46	1.36	1.68	1.58	0.169	0.0255	0.96^a	1.53^b	1.75^c	0.085

[1] L1, L2, L3, L4, L5, and L6 were levels of alfalfa pellets offered to support at least 0, 15, 30, 45, 60, and 75 g/day of tissue gain and 0, 1.5, 3.0, 4.5, 6.0, and 7.5 g/day of clean mohair fiber growth, respectively, based on NRC (2007) requirements.
[2] 3 weeks periods within each 12 weeks phase.
[3] P value for the linear effect of level of alfalfa pellets offered in phase 1 ($P<0.05$).
[4] Phase 1 was 12 weeks in length with different levels of alfalfa pellets offered; phase 2 was 12 weeks in length with ad libitum intake of alfalfa pellets subsequent to phase 1. a,b,c Means in a row within period grouping without a common superscript differ ($P<0.05$).

period 2. Treatment did not impact mohair fiber growth or yield ($P>0.05$). Yield increased as period advanced during phase 1 ($P<0.05$). Mohair fiber diameter increased linearly ($P<0.05$) as the level of offered feed increased. Diameter was lower in period 1 vs. 2 and 3 ($P<0.05$). Medullation was similar among treatments and periods ($P>0.05$).

In phase 2, DM intake increased linearly as the level of offered feed in phase 1 increased ($P<0.05$) (Table 1). Intake of DM was greater in periods 2 and 3 compared with period 1 ($P<0.05$). BW at the end of phase 2 and tissue gain increased linearly ($P<0.05$) with increasing level of feed offered in phase 1. Tissue gain decreased as period of the phase advanced, ranking ($P<0.05$) period 1>2>3. The ratio of ADG:DM intake decreased linearly as the level of feed offered in phase 1 increased ($P<0.05$) and ranked period 1>2>3 ($P<0.05$). Mohair fiber growth was not different among levels of feed offered in phase 1, although values for L4 and L5 were relatively high compared with other treatments. In contrast to tissue gain, mohair fiber growth increased as period of phase 2 advanced, ranking ($P<0.05$) period 1<2<3. Mohair yield in phase 2 was high relative to that in phase 1 and decreased as period of phase 2 increased ($P<0.05$). Mohair fiber diameter and medullation increased linearly as the level of offered feed in phase 1 increased ($P<0.05$) and increased as period advanced, ranking ($P<0.05$) period 1<2<3.

3.2. Digestibility and metabolizability

Linear increases in intake of DM, OM, CP, and NDF in phase 1 occurred as the level of offered feed increased ($P<0.05$; Table 2). There were no treatment effects in digestibilities ($P>0.05$), resulting in linear increases in intake of digested DM, OM, CP, and NDF ($P<0.05$).

In phase 2, intake of DM, OM, CP, and NDF also increased linearly with increasing level of offered feed in phase 1 ($P<0.05$; Table 2). Digestibility DM, OM, CP and NDF increased linearly with increasing level of offered feed ($P<0.05$). As a consequence, intake of digested DM, OM, CP, and NDF increased linearly with increasing level of offered feed in phase 1 ($P<0.05$).

Phase 1 MEI in MJ/day and kJ/kg $BW^{0.75}$ increased linearly with increasing level of offered feed ($P<0.05$; Table 3). ME used for mohair growth in MJ/day and kJ/kg $BW^{0.75}$ was similar among levels of feed offered in phase 1 ($P>0.05$). ME

Table 2
Effects of the level of feed intake on intake and digestion by Angora wethers.

Item	Treatment [a]						SEM	Linear P value [b]
	L1	L2	L3	L4	L5	L6		
Phase 1 [c]								
DM								
Intake (g/day)	508	555	622	693	804	897	39.6	0.0001
Digestion (%)	64.2	59.7	59.5	62.6	60.0	56.1	3.14	0.1731
Digestion (g/day)	326	325	366	434	482	500	28.0	0.0001
OM								
Intake (g/day)	448	490	549	611	710	792	34.9	0.0001
Digestion (%)	65.3	60.9	60.8	63.6	61.0	57.3	3.06	0.1560
Digestion (g/day)	293	293	330	389	432	450	24.6	0.0001
CP								
Intake (g/day)	90	99	111	123	143	160	7.1	0.0001
Digestion (%)	75.9	72.2	72.9	74.0	72.2	70.4	2.62	0.2342
Digestion (g/day)	69	70	80	92	103	112	5.6	0.0001
NDF								
Intake (g/day)	242	265	297	331	384	429	18.9	0.0001
Digestion (%)	53.8	47.3	47.2	50.4	47.3	41.2	4.61	0.1334
Digestion (g/day)	131	121	138	168	183	173	17.5	0.0069
Phase 2 [c]								
DM								
Intake (g/day)	1013	1037	1076	1169	1179	1359	79.9	0.0022
Digestion (%)	65.7	64.6	66.3	69.6	69.5	71.4	1.59	0.0014
Digestion (g/day)	668	671	723	814	821	974	64.7	0.0006
OM								
Intake (g/day)	894	915	949	1031	1040	1198	70.5	0.0022
Digestion (%)	68.0	66.9	68.5	71.7	71.4	73.4	1.69	0.0012
Digestion (g/day)	611	614	659	740	744	884	59.4	0.0005
CP								
Intake (g/day)	180	185	191	208	210	242	14.2	0.0022
Digestion (%)	78.1	76.8	78.5	80.4	79.1	81.5	1.22	0.0181
Digestion (g/day)	141	142	151	168	166	197	1.81	0.0014
NDF								
Intake (g/day)	484	495	514	558	563	649	38.2	0.0022
Digestion (%)	53.5	52.9	54.4	59.5	58.8	61.6	2.10	0.0011
Digestion (g/day)	260	262	285	332	332	401	28.5	0.0003

[a] L1, L2, L3, L4, L5, and L6 were levels of alfalfa pellets offered to support at least 0, 15, 30, 45, 60, and 75 g/day of tissue gain and 0, 1.5, 3.0, 4.5, 6.0, and 7.5 g/day of clean mohair fiber growth, respectively, based on NRC (2007) requirements.

[b] P value for the linear effect of level of alfalfa pellets offered in phase 1 ($P<0.05$).

[c] Phase 1 was 12 weeks in length with different levels of alfalfa pellets offered; phase 2 was 12 weeks in length with ad libitum intake of alfalfa pellets subsequent to phase 1.

Table 3
Effects of the level of feed intake on energy utilization by Angora wethers.

Item	Treatment [a]						SEM	Linear P value [b]
	L1	L2	L3	L4	L5	L6		
Phase 1 [c]								
ME intake								
MJ/day	5.39	5.24	6.00	7.15	7.89	8.04	0.506	0.0001
kJ/kg $BW^{0.75}$	622	600	688	796	806	816	45.7	0.0001
ME for mohair growth								
MJ/day	0.77	0.68	0.81	0.97	0.88	0.79	0.066	0.1405
kJ/kg $BW^{0.75}$	90	78	93	110	90	82	8.2	0.8635
ME for tissue gain								
MJ/day	0.55	1.23	1.88	2.08	2.32	2.77	0.213	0.0001
kJ/kg $BW^{0.75}$	61	141	223	233	238	286	25.3	0.0001
ME for maintenance [d]								
MJ/day	4.07	3.33	2.99	4.10	4.69	4.48	0.486	0.0860
kJ/kg $BW^{0.75}$	471	388	348	453	479	447	46.3	0.4767
Phase 2 [c]								
ME intake								
MJ/day	10.93	11.00	12.02	13.50	13.59	16.32	1.170	0.0009
kJ/kg $BW^{0.75}$	995	1006	1077	1133	1136	1272	65.4	0.0022
ME for mohair growth								
MJ/day	0.92	0.92	0.93	1.04	1.08	0.89	0.058	0.3894
kJ/kg $BW^{0.75}$	85	85	87	89	91	71	6.76	0.3483
ME for tissue gain								
MJ/day	3.85	3.38	3.63	3.26	3.03	3.70	0.411	0.5317
kJ/kg $BW^{0.75}$	358	322	344	279	257	299	43.7	0.1381
ME for maintenance [d]								
MJ/day	6.15	6.70	7.46	9.20	9.49	11.73	1.416	0.0032
kJ/kg $BW^{0.75}$	551	599	647	765	788	902	97.5	0.0055

[a] L1, L2, L3, L4, L5, and L6 were levels of alfalfa pellets offered to support at least 0, 15, 30, 45, 60, and 75 g/day of tissue gain and 0, 1.5, 3.0, 4.5, 6.0, and 7.5 g/day of clean mohair fiber growth, respectively, based on NRC (2007) requirements.

[b] P value for the linear effect of level of alfalfa pellets offered in phase 1 ($P<0.05$).

[c] Phase 1 was 12 weeks in length with different levels of alfalfa pellets offered; phase 2 was 12 weeks in length with ad libitum intake of alfalfa pellets subsequent to phase 1.

[d] Difference between ME intake and ME used for tissue gain and clean mohair fiber growth assuming the requirements of 37.2 and 157 kJ/kg, respectively (NRC, 2007).

used for tissue gain increased linearly as the level of offered feed increased ($P<0.05$), and ME_m was similar among treatments ($P>0.05$).

In phase 2, MEI increased linearly with increasing level of feed offered in phase 1 ($P<0.05$; Table 3). The amount of ME in MJ/day and kJ/kg $BW^{0.75}$ used for mohair fiber growth was not influenced by treatment ($P>0.05$). ME used for tissue gain was similar among treatments ($P>0.05$), and ME_m increased linearly as the level of feed offered in phase 1 increased ($P<0.05$).

4. Discussion

4.1. Feed intake and digestion

Greater amounts of feed offered in phase 1 than initially planned contributed to greater than projected MEI in phase 1. For example, MEI for the L1 treatment was greater than the assumed ME_m requirement of 473 kJ/kg $BW^{0.75}$ (Luo et al., 2004; NRC, 2007). Another factor that may have resulted in relatively high MEI in phase 1 was the assumption of a relatively low level of energy lost through CH_4 emission (i.e., 3.5% of GE intake). Nonetheless, levels of offered feed in phase 1 resulted in a wide range in MEI of 194 kJ/kg $BW^{0.75}$, with MEI for L6 31% greater than for L1.

Based on assumed requirements for ME_m, tissue gain, and clean mohair growth of 473 kJ/kg $BW^{0.75}$, 37.2 kJ/g, and 157 kJ/g, respectively (Luo et al., 2004; NRC, 2007), and without considering nutrient partitioning, MEI estimated during the digestibility measurement period of phase 1 was adequate to support 28, 23, 45, 56, 66, and 68 g/day of tissue gain and 2.8, 2.3, 4.5, 5.6, 6.6, and 6.8 g/day of clean mohair fiber growth for L1, L2, L3, L4, L5, and L6, respectively. However, because of nutrient partitioning, neither those levels nor those used to determine quantities of feed offered were obtained. That is, with low feed intake in phase 1 it was expected that mohair fiber growth would, to an unknown extent, be greater than assumed and tissue gain might be less, depending on whether and to what extent ME_m was decreased by limited nutrient intake.

After a period of restricted feed intake, in many instances feed intake by ruminant livestock is greater than expected based on BW and diet composition (Galyean and Goetsch, 1993). Thus, it may seem surprising that DM intake in phase 2 increased rather than decreased as the level of feed offered in phase 1 increased. However, change in DM intake relative to BW was only from 4.88 for L1 to 5.21% BW for L6. Nonetheless, effects of treatment on DM intake and ADG: DM intake in phase 2 could have resulted from impact on the digestive tract. Gastrointestinal tract mass relative to BW presumably increased with increasing level of MEI in phase 1 (McLeod and Baldwin, 1997). This could have been accompanied by increasing capacity for digesta in phase 2, thereby lessening impact on physical constraints to feed intake, and also would have increased the energy requirement for maintenance because of the high metabolic activity of splanchnic tissues (Johnson et al., 1990). Relatedly, decreases in ADG:DM intake in phase 2 as period advanced and as the level of feed offered in phase 1 increased were presumably consequences of factors such as decreasing tissue gain during phase 2, relatively high mass of tissue to be maintained at the beginning of phase 2, including the gastrointestinal tract, and increasing energy concentration in tissue being accreted.

The lack of treatment effects on digestibilities in phase 1 and linear increases in phase 2 as the level of feed offered in phase 1 increased suggests relatively little effect of intake level in the range observed in phase 1 on rate of passage of digesta through the gastrointestinal tract compared with influence of greater levels of intake in phase 2. Factors responsible for slightly higher digestibilities in phase 2 than in phase 1 are unclear.

4.2. ME_m

Although MEI for all treatments in phase 1, including L1, was greater than the assumed ME_m requirement, ME_m estimated based on MEI, levels of tissue and mohair fiber gain, and ME requirements of Luo et al. (2004) and NRC (2007) were similar or lower. The average of values in phase 1 was 431 kJ/kg $BW^{0.75}$ compared with the requirement of 473 kJ/kg $BW^{0.75}$. A slightly lower average ME_m in phase 1 compared with the requirement, as well as lower values for phase 1 vs. 2 within individual treatments, could have involved limited activity in relatively small pens with individual housing compared with many observations from group settings in the database used by Luo et al. (2004).

Relatively high ME_m estimates in phase 2, which increased with increasing level of feed offered in phase 1, probably relate at least partially to an invalid assumption regarding the ME requirement for tissue gain. That is, it is likely that fat and energy concentrations in tissue being gained were greater in phase 2 vs. 1 and increased during phase 2 with increasing level of feeding in phase 1 because of positive effects on BW at the beginning of phase 2. However, expected effects of level of nutrient intake on mass and energy use by energetically expensive support tissues such as the gastrointestinal tract and liver in the latter part of phase 1 for treatments with highest levels of intake and throughout phase 2 are in line with observed differences in ME_m between phases and among treatments in phase 2.

4.3. Mohair fiber growth and characteristics

The lack of effect of the level of feed offered in phase 1 on mohair fiber growth in phase 1 depicts the considerable ability of Angora goats to partition nutrients to skin follicles. This was also observed in the study of Sahlu et al. (1999b) in which 14-month old Angora wethers were subjected to similar degrees of nutrient restriction in kg/day of DM intake as in the present experiment. Although, in that study tissue loss occurred with the lowest intake levels. Converse to the results of the present experiment, nutrient restriction in the study of Sahlu et al. (1999b) decreased mohair fiber growth during that period of time, but the magnitude of effect was not marked (i.e., 15.2 and 18.1 g/day clean mohair fiber growth for the lowest and highest intake levels, respectively). The results of the present experiment indicate that nutrient partitioning also occurs in relatively young Angoras with appreciable capacity for tissue growth and levels of feed intake near and above the ME_m requirement.

Increases in mohair fiber diameter in both phases as the level of offered feed in phase 1 increased are not in accordance with similar mohair fiber growth among treatments. If it is assumed that endogenous (i.e., recycled) nutrients contributed more to skin follicle nutrition with high vs. low levels of offered feed, then nutrient source origin (i.e., endogenous vs. dietary) may have impacted diameter. This is supported by findings of Sahlu et al. (1999b) with 14-month old Angoras in which treatment means of tissue growth ranged from −25 to 7 g/day, although a slight increase in clean mohair fiber growth with increasing level of intake occurred in contrast to no effect in the present experiment. The difference in mohair fiber diameter between phases 1 and 2 of the present experiment and change with advancing period of phase 2, along with increasing medullation from period 1 to 3 in phase 2, probably reflect expected shifts in fiber characteristics with increasing age from 6 months to 1 year. That mohair fiber growth for 6 L in phase 1 was similar to that in phase 2 with generally higher levels of DM intake, implying that with all treatments mohair fiber growth was near maximal given the relatively young age and low BW of these wethers.

Tissue gain in phase 1 was not correlated with that in phase 2 or with mohair fiber growth in either phases ($P>0.05$). The lack of correlation between tissue and mohair fiber growth is not surprising given the levels of offered feed. That is, it appears that even with the L1 treatment, nutrient absorption and partitioning in phase 1 were adequate for tissue maintenance and a set level of mohair fiber growth. Higher levels of nutrient absorption with the L2, L3, L4, L5, and L6 treatments in phase 1 resulted in greater levels of tissue gain without impact on mohair fiber growth. The same was essentially true in phase 2, although based on estimates of ME_m with a constant ME requirement for tissue gain assumed, it would appear that higher levels of offered feed in phase 1 resulted in accretion of tissue relatively high in fat and energy during phase 2. Lower levels of offered feed in phase 1 than employed in the present experiment, which would elicit tissue mobilization to support mohair fiber growth, could increase the likelihood of a significant relationship between tissue gain/loss and mohair fiber growth. However, as in the present experiment, Sahlu et al. (1999b) did not observe significant relationships between tissue gain/loss and clean mohair fiber gain by 14-month old Angora wethers during periods of feed restriction or realimentation, with tissue mobilization occurring for some treatments during the restriction phase.

Mohair fiber growth in phase 2 was positively correlated with growth in phase 1 ($r=0.66$; $P<0.01$). This relationship presumably was due to two factors, one of which is direct effect of the treatments of different levels of feeding in phase 1. The second factor is normal variability among animals in capacity for mohair fiber growth. With different levels of intake not restrictive to mohair fiber growth given the impact of nutrient partitioning, Angoras with high potential for mohair fiber growth would display this capacity regardless of the particular level of intake. This influence is supported by a significant effect ($P<0.01$) of mohair fiber growth in phase 1 included as a covariate in the model for analysis of mohair fiber growth in phase 2.

4.4. Practical considerations

In terms of the entire production system component represented by this 24 weeks experiment, for overall mohair fiber growth higher levels of feeding in phase 1 might seem advantageous. However, earlier it was postulated that these treatments caused relatively high levels of fat accretion. Although the treatments resulted in similar total mohair fiber growth in both phases, there was an advantage to lower levels of offered feed in phase 1 in lower fiber diameter in both phases. Another notable advantage of the lower levels of feeding in phase 1 was more efficient production of mohair fiber growth relative to DM intake throughout the 24 weeks experiment, with an efficiency for the L1 treatment 58% greater than that for the L6 treatment. However, long-term benefit from this difference would depend largely on the subsequent feeding program necessary to address the incomplete compensation by tissue gain in phase 2 for limited accretion in phase 1, with a difference between L1 and L6 wethers in mass of tissue gain during the entire experiment of approximately 4 kg. Another important consideration is the potential for long-term adverse impact that such a difference in final BW at this age due to a limited nutritional plane might have on mature size and lifetime productivity.

Based on these findings, from previous experience producers should first select the maximal target rate of mohair fiber growth. The next decision is the rate of tissue gain to be achieved, taking into account a potential advantage of low levels in terms of mohair fiber diameter but disadvantages posed by increased levels of feeding needed later to compensate for the limited early rate of tissue gain as well as potential negative effect on mature size eventually attained and impact on lifetime productivity. Though not conclusively discerned in this study, it would appear that high levels of feeding Angora goats from 6 months to 1 year of age could have deleterious effects on efficiency of mohair fiber growth relative to DM intake through promotion of high levels of tissue fat accretion. Thus, a moderate plane of nutrition throughout the post-weaning period would seem preferable to balance considerations of fiber diameter and medullation and rate of tissue gain taking into account the effects and implications on efficiency of feed utilization for mohair fiber production, eventual mature size achieved, and long-term productivity.

5. Conclusions

Growing Angora goats between 6 months and 1 year of age partition nutrients to mohair fiber growth at the expense of tissue gain with limited levels of intake above the maintenance requirement. Realimentation likewise does not affect mohair fiber growth but increases tissue gain. However, with marked restrictions of nutrient intake, subsequent tissue gain during realimentation may not be fully compensatory. High levels of feeding from early postweaning to 1 year of age are not advantageous in terms of mohair fiber growth or tissue gain, and potential for relatively high fat deposition late in the feeding period is a concern at least in regards to efficiency of feed usage for mohair fiber growth.

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