ABSTRACT: Twelve mature Angora does were used in a replicated 3 × 3 Latin square to determine effects of feeding level on energy utilization. Fiber growth and change in tissue (nonfiber) mass were determined in the first 4 wk of 6-wk periods, preceded by 14 or 18 d of adaptation. Determination of ME intake and gas exchange measures occurred in wk 4, followed by feeding near maintenance, then fasting in wk 5 and 6 to determine the ME requirement for maintenance (ME\textsubscript{m}). A 60% concentrate diet was fed at levels to approximate 100, 125, and 150% of assumed ME\textsubscript{m} [low, medium (med), and high, respectively]. Digestibilities and diet ME/GE were not affected by treatment with different amounts of feed offered and subsequent intake near ME\textsubscript{m}. Heat energy during fasting (261, 241, and 259 kJ/kg of BW\textsuperscript{0.75}; SEM = 8.7) and efficiency of ME used for maintenance (71.6, 69.6, and 69.2%; SEM = 2.29) were similar among treatments, although ME\textsubscript{m} differed (P < 0.04) between med and high (365, 344, and 377 kJ/kg of BW\textsuperscript{0.75} for low, med, and high, respectively; SEM = 10.3). Tissue gain was less (P < 0.01) for low than for the mean of med and high (MH; 0.6, 23.7, and 29.8 g/d), although clean fiber growth only tended (P < 0.09) to differ between low and MH (5.60, 6.57, and 7.36 g/d for low, med, and high, respectively; SEM = 0.621). Intake of ME was greater (P < 0.01) for MH than for low (6.87, 8.22, and 8.41 MJ/d for low, med, and high, respectively). Total heat energy was less (P < 0.02) for low vs. MH and tended (P < 0.07) to be greater for high than for med (6.03, 6.31, and 6.77 MJ/d); mobilized tissue energy was low but greater (P < 0.02) for low vs. MH (0.16, 0.01, and 0.04 MJ/d for low, med, and high, respectively). Efficiency of ME use for fiber growth was similar among treatments (17.2, 16.3, and 17.7% for low, med, and high, respectively; SEM = 1.61). In conclusion, efficiency of ME use for fiber growth was similar to the NRC recommendation regardless of feeding level, although ME\textsubscript{m} was decreased perhaps because of experimental conditions used. Energy appeared partitioned to fiber growth, but preferential usage was not complete possibly because energy metabolism for tissue accretion reached a plateau with the greatest feeding level.

Key words: Angora, energy, goat, mohair fiber

INTRODUCTION

Nutrient requirements of goats have not been studied as extensively as those of beef and dairy cattle and sheep. Furthermore, Angora goats have received less research attention than meat or dairy goats, particularly in the last 10 to 20 yr because animal numbers have declined in response to change in production profitability (Sahlu et al., 2009). Nonetheless, Luo et al. (2004) attempted to address energy and protein needs of Angora goats by constructing a database of treat-
Animals and Diets

Twelve mature Angora does, approximately 3.55 yr of age (SEM = 0.014), were used in an experiment with 4 replicate 3 × 3 Latin squares. Before the experiment, does were treated for internal parasites with Cydectin (Fort Dodge Animal Health, Overton Park, KS). At most times during the experiment, does resided in 1.05 × 0.55 m elevated pens with expanded metal floors. At other times does were housed in metabolism crates. Water was available ad libitum.

The diet was 60% concentrate (Table 1). Treatments were 3 levels of offered feed: 100, 125, and 150% [low, medium (med), and high, respectively] of an assumed ME requirement for maintenance (ME_{med}) of 438 kJ/kg of BW^{0.75} (AFRC, 1998), with feedstuff ME concentrations of NRC (1981) used. Equal diet amounts were fed at 0800 and 1600 h.

**Measurements**

There were three 6-wk periods, with periods 1, 2, and 3 preceded by 14, 18, and 18 d of adaptation to level of feeding, respectively. Because the respiration calorimetry system held 4 animals simultaneously, does were grouped into 4 measurement sets of 1 animal per treatment. Animal sets began the experiment at different times.

Does were weighed unshrunk before feeding at 0800 h at the beginning and end of periods and when different measurement periods began and ended. The whole body was shorn before adaptation to feeding levels in period 1, and mohair fiber was clipped using a small Oster (Milwaukee, WI) clipper with a number 40 blade from a defined mid-side area of skin (10 × 10 cm), as described by Reis and Tunks (1976), that was collected separately. The average ratio of fiber of the mid-side patch to that of the whole body was used to estimate daily whole body fiber growth during periods from fiber harvested from the same mid-side patch area on the last day of wk 4 (i.e., 28-d period of fiber growth for each period). The whole body was not shorn at multiple times to minimize stress and avoid error introduced from inevitable loss of short fibers. Use of the ratio of fiber in the mid-side patch area to that of the whole body to predict whole body production (Squires, 1964) was felt preferable to a prediction of fiber-producing skin area based on an assumed function of BW and percentage of skin producing fiber. Tissue gain (i.e., nonfiber) was determined as the difference between whole body ADG and daily fiber growth in wk 1 to 4 of each period (i.e., 28 d). Mid-side patch fiber samples were used to determine clean yield (ASTM, 2003).

Feed intake and collections of feces and urine occurred over the 7 d of wk 4. On the last 2 d of wk 4, gas exchange was determined. On the first 8 d of wk 5 to 6, all does were fed at near the ME_{med} level. Feces and urine were collected on the last 4 d of this period, and on the last 2 d gas exchange measurements were made. Thereafter, does were fasted for 4 d, with gas exchange measured and urine collected on the last 2 d.

Feed was sampled daily during times of fecal and urine collections and gas exchange measurements, with formation of composite samples. When present, orts were collected and 10% aliquot samples were used to form composites for nutrient balance periods. Feces were collected in wire-screen baskets placed under the floor of metabolism crates, and urine was collected through a funnel into plastic buckets containing 20 mL of 10% (vol/vol) sulfuric acid. Subsamples (15%) of feces and urine were collected daily and stored at −20°C. Feed, feed refusals, and fecal samples were first dried in a forced-air oven at 55°C for 48 h, then ground to pass through a 1-mm screen. Feed and feed refusal samples were analyzed for DM, ash, N, GE (AOAC, 1990), and NDF (filter bag technique; Ankom Technology Corp., Fairport, NY), and fecal samples were analyzed for DM, ash, GE, N, and NDF. Urine samples were as-

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**Table 1. Composition of the diet fed to Angora does (DM basis)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredient, %</td>
<td></td>
</tr>
<tr>
<td>Coarsely ground alfalfa hay</td>
<td>40.0</td>
</tr>
<tr>
<td>Ground corn</td>
<td>50.0</td>
</tr>
<tr>
<td>Soybean meal, solvent, 49% CP</td>
<td>5.0</td>
</tr>
<tr>
<td>Molasses</td>
<td>3.0</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>0.7</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.3</td>
</tr>
<tr>
<td>Vitamin A, D, and E premix[^1]</td>
<td>0.5</td>
</tr>
<tr>
<td>Trace mineral salt supplement[^2]</td>
<td>0.5</td>
</tr>
</tbody>
</table>

\[^1\]Premix: 2,200 IU/g of vitamin A, 1,200 IU/g of vitamin D\(_3\), and 2.2 IU/g of vitamin E.

\[^2\]Supplement: 95 to 98% NaCl and at least 2,400 mg/kg of Mn, 2,400 mg/kg of Fe, 500 mg/kg of Mg, 320 mg/kg of Cu, 110 mg/kg of Co, 70 mg/kg of I, and 50 mg/kg of Zn.

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**Materials and Methods**

The protocol for the experiment was approved by the Langston University Animal Care and Use Committee.

**Chemical composition**

<table>
<thead>
<tr>
<th>Item</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash, % of DM</td>
<td>5.8</td>
</tr>
<tr>
<td>NDF, % of DM</td>
<td>25.1</td>
</tr>
<tr>
<td>CP, % of DM</td>
<td>14.8</td>
</tr>
<tr>
<td>GE, MJ/kg of DM</td>
<td>18.7</td>
</tr>
</tbody>
</table>
sayed for DM (lyophilization; model CRVP-195P Dura Stop, FTS Systems, Stone Ridge, NY), and N and GE concentrations were determined with dried samples.

For calorimetry measures, does were moved into a room with 4 metabolic crates fitted with head-boxes. The indirect open-circuit calorimetry system was described previously by Tovar-Luna et al. (2007). The concentration of O2 was analyzed using a fuel cell FC-1B analyzer (Sable Systems, Las Vegas, NV). Concentrations of CO2 and CH4 were measured using infra-red analyzers (FC-1B for CO2 and MA-1 for CH4; Sable 1B O2 analyzer (Sable Systems, Las Vegas, NV). Air was first analyzed for CH4 then for CO2 and O2. Before the gas exchange measurements, validity and accuracy of expired CO2 and inspired O2 flows were checked with ethanol combustion with the same flow rates used during measurements. Before each test, analyzers were calibrated with reference gas mixtures (19.5 and 20.5% O2, 0.0 and 1.5% CO2, and 0.0 and 0.3% CH4). Temperature (20 to 23°C) in the calorimetry room was maintained with a window air conditioning/heating unit (Carrier, Farmington, CT), and humidity was 50 to 55% through use of a dehumidifier (Whirlpool, Benton Harbor, MI). The natural photoperiod was mimicked by use of fluorescent lights.

Calculations

Intake of ME (MEI) was the difference between GE intake and energy losses in feces, urine, and CH4. Heat energy (HE) was estimated based on the Brouwer (1965) equation from O2 consumption and CO2 and CH4 production on days of gas exchange measurement, as well as urinary N excretion. Energy lost as CH4 was estimated as total CH4 emitted in L/d × 39.5388 kJ/L (Brouwer, 1965). Recovered energy (RE) was determined as the difference between MEI and HE.

Recovered energy in fiber (REf) was based on fiber growth and DM and GE concentrations in unwashed and washed or clean fiber. Recovered energy in tissue gained (REgt), HE associated with tissue gain (HEgt), and ME required for tissue gain (MEgt) were based on tissue gain, energy concentration in accreted tissue of 23.9 kJ/g (AFRC, 1998), and efficiency of ME use for tissue gain (%) from the equation of AFRC (1998) for unpelletized diets of (0.78 × dietary ME/GE, %) + 0.6. Heat energy associated with fiber growth (HEx) was the difference between HE and the sum of ME and HEgt. Metabolizable energy used for fiber growth (MEgt) was the sum of REf and HEx. When there was tissue loss rather than gain, it was assumed that mobilized tissue energy was used for maintenance (HEmt), with a tissue energy concentration of 23.9 kJ/g. There were only a small number of observations with tissue loss, and values were relatively small in magnitude. When mobilized, tissue energy substituted for dietary ME used for maintenance and, thus, was not considered in calculating HEgt.

The efficiency of ME used for maintenance (%; km) was estimated as 100 minus the slope of the regression of HE against MEI when fed near MEm and fasted. The MEm was fasting HE divided by km as a fraction. Efficiencies of use of ME were estimated for unwashed and clean fiber in percentage as REf divided by MEf. Metabolizable energy intake was only used to estimate RE, and RE was not employed to determine other measures. Because HEgt and, therefore, MEgt were estimated based on HE rather than MEI, MEgt, MEgtgt, and MEgt may not sum to MEI, as is also true for similarity between RE and the sum of REgt and REf.

Statistical Analyses

Data in the first 4 wk of periods and later when intake was limited near MEm were analyzed separately. Data were analyzed with the MIXED procedure (SAS Inst. Inc., Cary, NC; Littell et al., 1996) with a model consisting of feeding level, period (repeated measure), and doe (random). With the 14 or 18 d between periods and a lack of substantial differences among treatments in level of intake, no carryover effects were assumed. The effect of replicate square was nonsignificant (P > 0.10) and, thus, was excluded from the model. Means were separated by use of 2 orthogonal contrasts, low vs. the mean of med and high (MH; low vs. MH) and med vs. high.

RESULTS

Intake Near MEm

Dry matter intake was slightly less for low vs. MH (P < 0.04) when offered feed was near MEm after the period of different feeding levels (Table 2). Similar differences occurred for intake of OM, NDF, N, and GE (P < 0.04, 0.05, 0.06, and 0.05, respectively). Digestibilities were not affected by previous offered feed level. Based on true protein digestibility of 88% and metabolic fecal CP of 2.67% DMI (Moore et al., 2004), predicted CP digestibility was 69.6 to 69.9%. Reasons for slightly greater observed values are not apparent.

Energy losses in methane and urine were not affected by treatment (Table 2). Intake of ME tended (P < 0.09) to be greater for MH vs. low. Metabolizable energy intake in kilojoules per kilogram of BW0.75 was as intended, although there were differences among animals (438 kJ/kg of BW0.75; SEM = 7.3). Nonetheless, fed HE was slightly less than MEI, resulting in positive RE means. Level of feed offered did not affect (P > 0.11) fed or fasting HE, RE, or km, although MEm was less (P < 0.04) for med vs. high. The km was slightly less than 73.8% predicted from the AFRC (1998) equation of (0.35 × dietary ME/GE, %) + 50.3.

Different Feeding Levels

Body weight was similar (P > 0.38) among levels of feeding; however, tissue gain was greater (P < 0.01) for MH vs. low (Table 3). Unwashed and clean fiber...
growth tended \((P < 0.07\) and 0.09, respectively) to be greater for MH vs. low. Variability in mohair fiber growth was intermediate to that observed by Sahlu et al. (1999a,b).

Intakes of DM, OM, NDF, N, and GE were less for low vs. MH \((P < 0.01;\) Table 3). Digestibilities of DM, OM, N, and GE were similar \((P > 0.22)\) among treatments and to values determined with intake near ME\(_m\). However, NDF digestibility was less for high vs. med \((P < 0.05)\). As with near ME\(_m\) intake, N digestion was slightly less than 69.4 to 69.8% predicted from relationships determined by Moore et al. (2004).

### Table 2. Body weight, feed intake, digestion, and energy measures for Angora does fed near the ME requirement for maintenance after different feeding levels

<table>
<thead>
<tr>
<th>Item</th>
<th>Level of feeding</th>
<th>Contrast, (P &lt; )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Med</td>
</tr>
<tr>
<td>BW, kg</td>
<td>35.6</td>
<td>36.6</td>
</tr>
<tr>
<td>Intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM, g/d</td>
<td>480</td>
<td>535</td>
</tr>
<tr>
<td>OM, g/d</td>
<td>453</td>
<td>504</td>
</tr>
<tr>
<td>NDF, g/d</td>
<td>131</td>
<td>144</td>
</tr>
<tr>
<td>N, g/d</td>
<td>11.2</td>
<td>12.6</td>
</tr>
<tr>
<td>GE, MJ/d</td>
<td>9.02</td>
<td>10.02</td>
</tr>
<tr>
<td>Digestion, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>75.2</td>
<td>75.3</td>
</tr>
<tr>
<td>OM</td>
<td>77.2</td>
<td>77.5</td>
</tr>
<tr>
<td>NDF</td>
<td>49.7</td>
<td>50.0</td>
</tr>
<tr>
<td>N</td>
<td>73.4</td>
<td>74.4</td>
</tr>
<tr>
<td>GE</td>
<td>75.0</td>
<td>75.5</td>
</tr>
<tr>
<td>Energy measure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME intake, MJ/d</td>
<td>6.06</td>
<td>6.74</td>
</tr>
<tr>
<td>Methane emission, MJ/d</td>
<td>0.41</td>
<td>0.46</td>
</tr>
<tr>
<td>Urinary excretion, MJ/d</td>
<td>0.30</td>
<td>0.37</td>
</tr>
<tr>
<td>Fed heat energy, MJ/d</td>
<td>5.53</td>
<td>5.64</td>
</tr>
<tr>
<td>Recovered energy, MJ/d</td>
<td>0.53</td>
<td>1.10</td>
</tr>
<tr>
<td>Fasting heat energy, kJ/kg of BW(^{0.75})</td>
<td>261</td>
<td>241</td>
</tr>
<tr>
<td>Efficiency of ME use for maintenance, %</td>
<td>71.6</td>
<td>69.6</td>
</tr>
<tr>
<td>ME requirement for maintenance, kJ/kg of BW(^{0.75})</td>
<td>365</td>
<td>344</td>
</tr>
</tbody>
</table>

\(^1\)Low, medium (med), and high = 100, 125, and 150% of an assumed ME requirement for maintenance; 12 observations/treatment.

\(^2\)Low vs. MH = low vs. mean of med and high.

\(^3\)Estimated as 100 minus the slope of the regression of heat energy against ME intake when fed near the ME requirement for maintenance and fasted.

### Table 3. Body weight, feed intake, and digestion for Angora does with different levels of feeding

<table>
<thead>
<tr>
<th>Item</th>
<th>Level of feeding</th>
<th>Contrast, (P &lt; )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Med</td>
</tr>
<tr>
<td>BW, kg</td>
<td>34.7</td>
<td>35.2</td>
</tr>
<tr>
<td>Tissue (nonfiber) gain, g/d</td>
<td>−0.6</td>
<td>23.7</td>
</tr>
<tr>
<td>Fiber growth, g/d</td>
<td>Unwashed</td>
<td>7.32</td>
</tr>
<tr>
<td></td>
<td>Washed or clean</td>
<td>5.60</td>
</tr>
<tr>
<td>Intake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM, g/d</td>
<td>547</td>
<td>646</td>
</tr>
<tr>
<td>OM, g/d</td>
<td>516</td>
<td>610</td>
</tr>
<tr>
<td>NDF, g/d</td>
<td>145</td>
<td>174</td>
</tr>
<tr>
<td>N, g/d</td>
<td>12.8</td>
<td>14.9</td>
</tr>
<tr>
<td>GE, MJ/d</td>
<td>10.25</td>
<td>12.03</td>
</tr>
<tr>
<td>Digestion, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>75.3</td>
<td>74.1</td>
</tr>
<tr>
<td>OM</td>
<td>77.5</td>
<td>77.5</td>
</tr>
<tr>
<td>NDF</td>
<td>47.1</td>
<td>48.1</td>
</tr>
<tr>
<td>N</td>
<td>73.8</td>
<td>72.9</td>
</tr>
<tr>
<td>GE</td>
<td>75.0</td>
<td>75.4</td>
</tr>
</tbody>
</table>

\(^1\)Low, medium (med), and high = 100, 125, and 150% of an assumed ME requirement for maintenance; 12 observations/treatment.

\(^2\)Low vs. MH = low vs. mean of med and high.
Energy loss in methane in megajoules per day (Table 4) and as a percentage of DE intake was similar among treatments (7.2, 6.6, and 6.5% for low, med, and high, respectively; SEM = 0.66). Urinary energy in MJ/d was greater for MH vs. low ($P < 0.01$) and as a percentage of DE intake was similar among treatments (3.7, 3.6, and 3.8% for low, med, and high, respectively; SEM = 0.20). Urinary N loss as a percentage of N intake was not different ($P > 0.17$) among treatments, with values numerically increasing as level of offered feed increased (9.8, 14.4, and 17.9% for low, med, and high, respectively; SEM = 3.82), suggesting a dietary N level well above the requirement.

Total HE was less for low vs. MH ($P < 0.02$) and tended to be greater for high vs. med ($P < 0.07$; Table 4). Differences in HE were much less than in MEI. Thus, total RE was approximately twice as great for MH vs. low ($P < 0.01$). Total RE was positive for all treatments, including low.

The $ME_m$ requirement in megajoules per day, based on BW$^{0.75}$ during wk 4 and the requirement determined in kilojoules per kilogram of BW$^{0.75}$ during wk 5 and 6, was similar among treatments (Table 4). Dietary ME used for maintenance did not differ among feeding levels either. Using regression analysis to estimate $ME_m$ of Freetly et al. (2006) by regressing RE (kJ/kg of BW$^{0.75}$) against MEI (kJ/kg of BW$^{0.75}$), the resultant equation from data of the present experiment [$RE = -213.8 + (0.5847 \times MEI)$ ($R^2 = 0.72$)] yielded a $ME_m$ of 366 kJ/kg of BW$^{0.75}$, which was very similar to the average of treatment means in the present experiment (i.e., 362 kJ/kg of BW$^{0.75}$). Tissue energy mobilized and used for maintenance was small for each treatment, but was greater for low vs. MH ($P < 0.02$). Heat energy associated with tissue gain was less for low vs. MH ($P < 0.01$). Heat energy in support of fiber growth was not affected by treatment ($P > 0.35$). Effects of treatment on REgt and MEgt were the same as on HEgt, in accordance with the method of estimation. Recovered energy in unwashed and clean fiber tended ($P < 0.06$ and 0.09, respectively) to be less for low vs. MH, although ME used for fiber growth did not differ among treatments.

**DISCUSSION**

**ME for Maintenance**

It was anticipated that $HE_m$ would be appreciable with low, which did not occur because of relatively small $ME_m$. Means of both $HE_m$ and $ME_m$ were positive but small for low, because when tissue was mobilized $HE_m$, $RE_m$, and $ME_m$ were set at 0, and when energy was accreted in tissues $HE_m$ was 0.

Fasting HE and $ME_m$ estimated when animals were fed near the assumed $ME_m$ requirement for 8 d after different levels of feeding for 4 wk were considerably less than expected based on findings of Luo et al. (2004), most importantly a $ME_m$ of 473 kJ/kg of BW$^{0.75}$ recommended by NRC (2007). Likewise, Puchala et al. (2007) observed greater $ME_m$ of 431 kJ/kg of BW$^{0.75}$ in grow-
ing Angora wethers with different levels of restricted MEI.

Several factors could have contributed to relatively small MEI estimates. It is sometimes assumed that 10% of MEI determined for confined animals, such as addressed by Luo et al. (2004), is attributable to activity (Goetsch et al., 2010). Presumably, the activity energy cost was minimal in the present experiment because of housing conditions. The relatively larger dietary ME/GE (AFRC, 1998) and limited rather than ad libitum housing conditions could have restricted MEI (Sahlu et al., 2004; Asmare et al., 2006; Tovar-Luna et al., 2007). Furthermore, determination of MEI from fasting HE following an 8-d period of limited consumption could have had an impact. For example, Tovar-Luna et al. (2010) determined fasting HE by lactating dairy goats immediately after ad libitum consumption compared with that following intake near MEI, noting MEI that was 41 kJ/kg of BW0.75 and 13% less for the latter condition.

A reason why DMI was not greater for high vs. med as intended is less than expected MEI. This probably contributed to greatest feed refusals among treatments for high. Refusals averaged 4.8, 7.6, and 16.3% of 573, 695, and 786 g/d (SEM = 19.3) of DM fed for low, med, and high, respectively. As a result, MEI as a percentage of MEI was less for low vs. MH and similar for med and high (133, 160, and 167%; SEM = 5.8). Similar REgt for med and high suggests little or no additional capacity for tissue accretion above med.

**Fiber Composition and Growth**

The energy concentration in clean fiber (19.7 ± 0.053 kJ/g) was slightly less than 23.7 kJ/g (ARC, 1980) assumed by Luo et al. (2004). Energy concentration in DM removed by washing was 27.7 kJ/g, indicating considerable DM with 0 or decreased energy concentration relative to wax or oil (e.g., wax: 40.8 kJ/g; Paladines et al., 1964). Nonetheless, because of the greater energy concentration in unwashed vs. clean fiber, kF was slightly greater for unwashed fiber.

The absence of significant effect of feeding level on clean fiber growth rate reflects nutrient partitioning to support fiber growth. This was also evident in an experiment of Puchala et al. (2007) with Angora goats 6 to 12 mo of age subjected to 6 different levels of intake for 12 wk, followed by 12 wk of ad libitum consumption. Clean fiber growth rate ranged from 4.7 to 5.7 g/d in the first phase and 5.8 to 6.8 g/d in the second. The similar range of values in the second phase compared with the present study most likely was a consequence of greater BW and the relatively lower plane of nutrition in the present experiment. However, in both experiments there were small increases in tissue gain and fiber growth, albeit in most cases nonsignificant, as plane of nutrition increased. Hence, perhaps nutrient partitioning to fiber growth should be viewed as a dampening of tissue gain rather than prevention. This could involve different arrays of nutrients best matching needs of fiber follicles and other tissues, such as internal and peripheral fat depots and muscle. In accordance, partitioning may vary with the nature of the diet, physiological maturity, and capacity for fiber growth as influencing the most appropriate nutrient array for tissue vs. fiber accretion. Because MEI as a percentage of MEI was similar between med and high in this study, with relatively greater feed refusals for high, it would appear that MEI was restricted by a plateau in DMI because of inadequate capacity for further energy metabolism with concomitant accretion in tissue or fiber or both given the specific characteristics of these animals and this diet.

**Energy Use for Fiber**

With a database of treatment mean observations from the literature, Luo et al. (2004) estimated a MEI of 157 kJ/g of clean mohair fiber. A kF of 15%, similar to that in the present experiment (17.0%; SEM = 1.42), was proposed based on an assumed energy concentration in clean fiber of 23.7%. These findings were the basis of nutrient requirement recommendations of NRC (2007) for Angora goats. Other kF estimates referenced by Luo et al. (2004) for sheep and Angora goats ranged from 16 to 20% (Langlands and Bowles, 1974; Graham and Searle, 1982; SCA, 1990), except for considerably greater values of NRC (1981) and AFRC (1993).

The sum of MEI, MEgt, and MEI was less than MEI. Likewise, the sum of REgt and REI was less than RE, estimated as the difference between MEI and HE. Ideally, these values would be similar. However, OM digestibility was approximately 3 percentage units greater than expected based on anticipated values for individual feedstuffs. It is possible that inaccuracies of measurement such as incomplete feces and urine collections contributed to this difference. Moreover, the estimate of MEI was the average during wk 4, with the last 2 d for measurement of HE. In some instances, feed intake can decrease slightly when animals are placed in head-boxes for gas exchange measurement. Although this was not viewed as a significant issue in this experiment, it may have led to slightly less MEI than the 7-d average reported for wk 4. Intake only on the 2 d of gas exchange measurement was not used because of relatively large variability with such short periods of measurement and influence of level of intake on days preceding the 2 d of HE determination. With the small amount of ME used for mohair fiber growth compared with that used for maintenance and tissue energy gain, relatively small overestimation of MEI would lead to appreciable overestimation of RE and, subsequently, REgt when determined as the difference between RE and REI. To put this into perspective, if actual MEI was 92, 86, and 92% of that determined for low, med, and high, respectively, RE estimated as the difference between MEI and HE would equal that determined with the current approach. Because of these considerations, HEI and MEI were based on HE and tissue gain.
obtained from the difference between whole body ADG and fiber growth, rather than derivation of RE from the difference between MEI and HE and subsequent partitioning of RE<sub>gt</sub> to estimate ME<sub>gt</sub> and HE<sub>gt</sub>, by assuming an efficiency of ME use for tissue gain, for ultimate estimation of ME<sub>t</sub> and HE<sub>t</sub> by difference.

The accuracy of estimating RE<sub>gt</sub> from ADG depends largely on the accuracy of the concentration of energy in tissue accreted or mobilized used. To evaluate the potential effect of the assumption employed in the present experiment on kf, alternative concentrations can be selected. However, a literature search did not reveal information available concerning the concentration of energy in tissue of mature Angora goats being accreted or mobilized. Nonetheless, Sahlu et al. (1999b) determined the chemical composition of the carcass, noncarcass pool, and whole body of Angora wethers approximately 17 mo of age that had been subjected to ad libitum intake for 40 d subsequent to different levels of intake for 41 d. Different levels of intake in the first part of the experiment did not affect the whole body energy concentration after ad libitum intake. However, body composition was determined only at this one time. Oman et al. (2000) observed greater digestible fat in carcass cuts of Angora compared with Boer × Spanish and Spanish intact males, although animals were approximately 7 mo of age at harvest and had been fed an 80% concentrate diet for 130 d. Cameron et al. (2001) noted similar moisture, ash, fat, and protein levels in the empty body, carcass, and noncarcass pool of Boer × Spanish, Spanish, and Boer × Angora wethers at 212 d of age after consumption of a concentrate-based diet for 16 wk.

Because of the lack of highly relevant data, 3 recently determined concentrations of energy in tissue being accreted or mobilized by other types of goats were used. Ngwa et al. (2009a) determined that an average energy concentration in tissue accreted by growing meat goats (3/4 Boer × 1/4 Spanish and Spanish) is 17.3 MJ/kg, unless there has been a prolonged limited nutritional intake for 40 d near maintenance and below. J. Appl. Anim. Res. 29:81–89.


Energy utilization by Angora goats


