Body composition and net energy requirements of Brazilian Somali lambs

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Abstract

The aim of this study was to determine the energy requirements for maintenance (NEm) and growth of 48 Brazilian Somali ram lambs with an average initial body weight of 13.47±1.76 kg. Eight animals were slaughtered at the trials beginning as a reference group to estimate the initial empty body weight (EBW) and body composition. The remaining animals were assigned to a randomised block design with eight replications per block and five diets with increasing metabolisable energy content (4.93, 8.65, 9.41, 10.12 and 11.24 MJ/kg dry matter). The logarithm of heat production was regressed against metabolisable energy intake (MEI), and the NEm (kJ/kg0.75 EBW/day) were estimated by extrapolation, when MEI was set at zero. The NEm was 239.77 kJ/kg0.75 EBW/day. The animal’s energy and EBW fat contents increased from 11.20 MJ/kg and 208.54 g/kg to 13.54 MJ/kg and 274.95 g/kg of EBW, respectively, as the BW increased from 13 to 28.70 kg. The net energy requirements for EBW gain increased from 13.79 to 16.72 MJ/kg of EBW gain for body weights of 13 and 28.70 kg. Our study indicated the net energy requirements for maintenance in Brazilian Somali lambs were similar to the values commonly recommended by the United States’ nutritional system, but lower than the values recommended by Agricultural Research Council and Commonwealth Scientific and Industrial Research Organization. Net requirements for weight gain were less compared to the values commonly recommended by nutritional system of the United States.

Introduction

The National Research Council is commonly used around the world to formulate diets and to evaluate feeding programmes in diverse conditions (Tedeschi et al., 2004). However, energy and nutrient requirements are based on wool sheep data (Regadas Filho et al., 2013). Researchers from academic and research institutions located in regions of semi-arid climate hypothesize that nutritional requirements of hair sheep may be different from those established in international systems of feed evaluation and requirements for small ruminants. Some studies have been conducted to determine energy and protein requirements of hair sheep (Silva et al., 2003; Gonzaga Neto et al., 2005; Costa et al., 2013). These studies have been conducted to compose a database in the future and provide an overall summary of the requirements for hair sheep. Hair sheep and their crosses are commonly used in meat production systems in tropical regions. They possess abilities to withstand hot and humid weather, tolerate intense sunshine, resist parasites, and utilize poor quality food (Costa et al., 2013).

A recent study carried by our team using the Brazilian sheep breed Santa Ines (Regadas Filho et al., 2013) and Morada Nova (Costa et al., 2013) confirmed the energy recommendations of the Institute National de la Recherche Agronomique (INRA, 1989), the Agricultural and Food Research Council (AFRC, 1993), and the Commonwealth Scientific and Industrial Research Organization (CSIRO, 2007).

Brazilian Somali arrived in Brazil in 1939, brought by farmers from Rio de Janeiro State, but it did not adapt well to the climatic conditions. The drier and hotter climates found in the northeast of the country were more adequate (Paiva et al., 2011). It is used preferentially for meat production and is well adapted to extensive and semintensive farming. Information on the Somali race is scarce; most studies on this breed are based on crossbred, dewormed (Merial Ivermectin; Pfizer Inc., New York, NY, USA; 200 g of ivermectin/kg of BW) and placed in individual stalls with feeding troughs to supply the diets and water. Wood shavings were used as bedding. After a 10 day adaptation period, eight animals were randomly selected and slaughtered to serve as a refer-

Materials and methods

Experiment site

The experiment was conducted in the Department of Animal Science at the Federal University of Ceara in Fortaleza, Ceara State, which is located in the Northeast of Brazil at 3° e 45’ South and 38°32’ West, 15.5 m asl. Humane care and harvest procedures followed protocols and guidelines of the Ethical Commission of Animal Exploitation (CEUA), University of Londrina, Brazil.

Animals, housing and feeding

The 48 Brazilian Somali used were non-castrated males, approximately 2 months of age, with an average initial body weight (IBW) of 13.47±1.76 kg BW. The animals were identified, dewormed (Merial Ivermectin; Pfizer Inc., New York, NY, USA; 200 g of Ivermectin/kg of BW) and placed in individual stalls with feeding troughs to supply the diets and water. Wood shavings were used as bedding. After a 10 day adaptation period, eight animals were randomly selected and slaughtered to serve as a refer-

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ence for the empty body weight (EBW) estimates and initial body composition. The procedures used to compute energy retained and maintenance energy requirement were similar to those of Loofgreen and Garrett (1968). The initial EBW was computed from shrunken body weight (SBW), and then initial empty body fat (EBF) and empty body protein (EBP) were estimated from EBW for each animal, using the average EBW, SBW, EBF, and EBP data from the baseline lamb of the appropriate group.

The remaining lambs (n=40) were randomly allocated to five treatments (8 animals/treatment) that consisted of diets with increasing levels of metabolizable energy (ME) (4.93, 8.65, 9.41, 10.12 and 11.24 MJ/kg DM). The ratios roughage:concentrate were 100:0, 80:20, 60:40, 40:60 and 20:80, respectively. The animals were fed diets as total mixed rations (TMR) twice daily (at 8 a.m. and 4 p.m.) ad libitum, allowing for up to 20% orts. Every day before feeding, the diet orts of each animal were removed and weighed for daily control.

The daily dry matter intake (DMI) was calculated as the difference between the weight of the diet offered and the orts. Table 1 shows the ingredients and chemical compositions of the diets.

**Determination of diet digestibility**

Digestibility trial was conducted at eight times during the experiment to determine the ME of the diet. Indigestible neutral detergent fibre (iNDF) was used as an internal marker to estimate apparent nutrient digestibility and faecal output. Faeces were collected directly in the rectum ampoule for three consecutive days every 15 days during the experiment, at 8 a.m. on the first day, at noon on the second day, and at 4 p.m. on the third day. The faeces samples were frozen (-20°C) and at the end of the experiment formed composite samples per animal/treatment. The samples were oven-dried to a constant weight at 55°C, ground to pass through a 1-mm screen using a Willey-type mill (MA-680; Marconi Ltda., Piracicaba, Brazil). The amount of iNDF in the faecal samples, orts, concentrates and Tifton-85 hay was obtained through waste in situ incubations over a period of 240 h in the rumen of a cow receiving a diet of Tifton-85 hay and concentrates based on corn grain, soybean meal, urea, limestone, dicalcium phosphate, sodium chloride and mineral premix. The roughage:concentrate ratio was 60:40. The incubations were conducted using nylon bags according to the methodology described by McDonald and Orskov (1979). After 240 h, the bags with the incubation residues were washed in water until the water became totally clear. Subsequently, the bags were boiled for 1 h in a neutral detergent solution. The remains were weighed and considered the iNDF. The faecal excretion (FE) was calculated according to the following equation: FE=iNDF intake (g/day)/iNDF faecal (g/g DM). The total digestible nutrient (TDN) was calculated according to Weiss (1999): TDN=Cpð+NFCD+aNDFom×EEd×2.25 (subscript means digestible). The dietary digestible energy (DE) was estimated as 4.409 Mcal/kg of TDN, and DE was converted to ME using an efficiency of 82% to convert DE to ME (National Research Council, 2000). The 82% is consistent with the findings of Tedeschi et al. (2002).

**Slaughtering procedures and samples collection**

The animals were weighed weekly to calculate average daily gain (ADG). When animals of a given treatment averaged 28 kg BW, all experimental animals (including other treatments) were slaughtered. Before slaughter, SBW was determined as the BW after 18 h of food and water fasting. At slaughter, the lambs were stunned using a cash knocker and killed by exsanguination from the jugular vein using conventional procedures. The protocols used to obtain the samples were similar to those of Costa et al. (2013). Blood was collected and weighed. The gastrointestinal tract was weighed full, then emptied, washed out and, after draining, weighed again, together with the organs and other body parts (carcass, head, skin, blood, full paw and tail). The body was separated into individual components, which were weighed separately. These included the internal organs (liver, heart, bladder, kidneys, reproductive tract and spleen, being combined lung+trachea and tongue+esophagus together), the cleaned digestive tract (rumen, reticulum, omasum, abomasum, and the small and large intestines) and fats (omental, perirenal, mesenteric and heart fats). Empty body weight was computed as the SBW at slaughter minus the digestive tract contents. All carcasses were weighed hot (approximately 1 h after collection) and then cooled (-4°C) for approximately 24 h. After 24 h of cooling, the chilled carcasses were weighed again and then longitudinally halved on a band saw. All body components were cut into small pieces using a band saw. The organs, full paw, head and the right half of the carcass were ground separately in an industrial meat grinder. Immediately, the samples were homogenized and sampled and placed in a forced ventilation oven at 55°C for 72 h. The samples were ground in a ball mill and stored in closed containers. After this procedure, the samples were defatted by extraction with ether in a Soxhlet apparatus (AOAC 1990; method number 920.39) for 12 h. After extraction, the samples were ground in a ball mill and stored in closed containers. The DM contents were

| Ingredient       | ME levels, MJ/kg |
|------------------|------------------|
|                  | 4.93             | 8.65 | 9.41 | 10.12 | 11.24 |
| Tifton-85 hay    | 100              | 80   | 60   | 40    | 20    |
| Concentrate<sup>o</sup> | 0               | 20   | 40   | 60    | 80    |
| Corn meal        | -                | 158.7| 684.5| 724.6 | 756.1 |
| Soybean meal     | -                | 806.5| 285.3| 248.8 | 225.9 |
| Urea             | -                | 30.0 | 12.5 | 11.2  | 5.0   |
| Limestone        | -                | -    | 5.4  | 6.6   | 0.07  |
| Dicalcium phosphate | -             | -    | -    | -     | 0.07  |
| Salt             | -                | 4.0  | 7.0  | 9.3   | 5.0   |
| Premix           | -                | 0.8  | 0.7  | 0.7   | 0.6   |

| Nutrient | DM, g/kg | 920.2 | 920.0 | 920.6 | 920.0 | 919.5 |
|----------|----------|-------|-------|-------|-------|-------|
| Ash      | g/kg DM  | 56.3  | 56.9  | 46.6  | 42.3  | 40.2  |
| CP       | g/kg DM  | 92.5  | 164.2 | 160.3 | 165.8 | 169.5 |
| EE       | g/kg DM  | 23.3  | 24.6  | 34.0  | 45.3  | 48.5  |
| NDF      | g/kg DM  | 721.8 | 601.1 | 473.5 | 343.4 | 212.4 |
| TC       | g/kg DM  | 327.9 | 754.3 | 758.9 | 746.6 | 740.8 |
| NFC      | g/kg DM  | 106.1 | 164.1 | 270.6 | 415.4 | 524.8 |
| TDN      | g/kg DM  | 347.8 | 576.8 | 608.8 | 668.5 | 745.0 |

ME, metabolizable energy; DM, dry matter; CP, crude protein; EE, ether extract; NDF, detergent fibre; TC, total carbohydrate; NFC, non-fibrous carbohydrate; TDN, total digestible nutrient. "Ingredients in concentrated portion of the diets: Ca, 7.5%; P, 3%; Fe, 16.500

Table 1. Ingredients and chemical composition of the experimental diet.
determined by placing samples in an oven at 105°C until a constant weight was reached. The ash and crude protein (CP) levels were determined from fat-free samples, following the method described above for experimental diet ingredients.

Data calculation

The procedures used to calculate the energy retained and the maintenance energy requirement were similar to those of Lofgreen and Garrett (1968). The initial EBW was computed from SBW, and then initial empty body fat (EBF) and empty body protein (EBP) were estimated from EBW for each animal, using the average EBW, SBW, EBF, and EBP data from the baseline ram lambs of each group. The EBF and EBP contents were determined according to their percentage in the empty body. The body corporal energy BCE was determined from the following equation (ARC, 1980): BCE = Y = a + bX + log EBW for the logarithms of body components, the net energy requirement for gain (NEg) for empty body weight gain (EBWG) was calculated using the methodology described by ARC (1980). We used ordinary least-squares (NEg) for empty body weight gain (EBWG) was calculated using the methodology described by ARC (1980). We used ordinary least-squares regression to obtain equations of the form Y = a + bX + log EBW for the logarithms of body fat (g), protein (g) and energy content (MJ) versus the logarithm of empty body weight (kg). Then, we derived equations of the form proposed by Regadas Filho et al. (2013), i.e.

\[ Y = a + bX + \log(EBW) \]

where Y = net energy (MJ/kg EBW gain) or protein (g/kg EBW gain) requirement (MJ/kg EBW gain) or fat content (g/kg EBW gain), EBW = empty body weight (kg), a = the intercept and b = the regression coefficient.

Heat production (HP) (kJ/kg 0.75 of EBW/day) was calculated as the difference between ME intake (MEI) (kJ/kg 0.75 of EBW/day) and retained energy (kJ/kg 0.75 of EBW/day). The antilog of the intercept of the linear regression between the logs of HP and MEI was used to estimate the maintenance requirements for NE (kJ/kg 0.75 of EBW/day; Lofgreen and Garrett, 1968). To convert the EBW NE requirements into BW NE requirements, adjustments were made by a linear regression equations between the EBWG and the BWG and also between the EBW and BW of all of the animals used in the experiment. The calculations were based on EBW to avoid the influence of the weight of the contents of the GIT in obtaining the prediction equations of nutritional requirements, for greater precision in estimates. The 1.23 factor, obtained of the relation BW/EBW, was used for convert such requirements expressed in Mca/kg for Mca/kg BW.

Chemical analyses

Concentrate, forage, TMR and refuse samples were dried in a forced air oven at 55°C for 72 h and then ground in a knife mill with a 1 mm screen (Wiley mill; Thomas Scientific, Philadelphia, PA, USA). The samples were analyzed to determine the contents of DM (AOAC, 1990; method number 930.15), ash (AOAC, 1990; method number 924.05), CP (AOAC, 1990; method number 984.13), ether extract (EE) (AOAC, 1990; method number 920.39), acid detergent fibre (ADF; AOAC, 1990; method number 973.18), NDF (Van Soest et al., 1991) and fibrous carbohydrates (FC) (FC considered as NDF corrected for ash and protein; Sniffen et al., 1992).

Statistical analysis

Statistical analyses were performed according to the following statistical model through the PROC MIXED of SAS (V 9.1):

\[ Y_{ij} = \mu + c_i + b_j + e_{ij} \]

where Yij = value observed in the plot that received treatment i in the block j; µ = overall mean; ci = fixed effect of treatment i; bj = random effect of the block j; ei = random error ~NID (0, 0.05). The least squares means were obtained by LSMEANS statement. An orthogonal partition of treatments effect into linear and quadratic degree effects was obtained following an analysis of variance (α=0.05). Linear regressions were adjusted using the PROC REG (SAS 9.0; 2007). The nonlinear regression model to estimate the NE requirement for maintenance was adjusted using the NLIN procedures of SAS 9.0 (Marquardt method).

Results and discussion

The ADG and the EBWG (g/day) increased linearly as the ME concentration in the diet increased: ADG (g/day)=17.219 (±2.347) ME−56.268 (±3.541) [r²=0.529; root of the mean square error (RMSE)=28.25; n=40]; EBWG (g/day)=3.049 (±3.032) (r²=0.586; RMSE=24.14; n=40). As expected, the final body weight (FBW), SBW, EBW, DMI and MEI showed quadratic effect (P<0.001) with increasing energy level in the experimental diets. In our study, changes in body energy content were correlated with the level of feed intake. Galvani et al. (2013) reported how it is important to consider the efficiency greater than that fixed by the National Research Council (2007) to convert DE to ME (0.82). Therefore, using constant values obtained from adult animals at the maintenance level of intake to calculate ME intake of growing lambs at any feeding level can lead to an overestimation of the efficiency of conversion of ME to NE. Vermorel and Bichel (1980) reported that the ratio ME/DE is generally much higher in growing. The ME/DE also depends on the chemical and physical composition diets and on feeding level. The energy intake affects HP due to an increase in mass and metabolic activity of the visceral organs. Accurate predictions of dry matter intake (DMI) and NE for growth (NEg) and maintenance (NEm) are highly dependent on the knowledge of the value of NE that accurately represents food offered. In the present study, the BWB, SBW, EBW, DMI and MEI showed a significant quadratic effect (P<0.001) with increasing energy level in the experimental diets. In our study, changes in body energy content were correlated with the level of dietary ME (r²=0.844; SEM=1.25). The nonlinear regression indicated that HP (Figure 1) increased exponentially as MEI increased. Using cattle, Turner and Taylor (1983) showed that HP is greater with increased
plane of nutrition, mainly due to an elevation in metabolism associated with the energy retention. Similarly, Williams and Jenkins (2003) proposed that ME consumed above the maintenance requirement is associated with an elevation of vital functions (support metabolism) and that this HP is driven by the amount of MEI. Overall HP is considered as the increase in heat production after feed intake by an animal at a thermoneutral temperature. Our studies with hair sheep (Regadas Filho et al., 2013; Costa et al., 2011) put in evidence as the heat of fermentation and the energy spent in the digestive processes, as well as the heat produced as nutrient metabolism, contribute to HP. Feed quality and quantity can influence the activity pattern and thereby alter HP and NEm requirement.

The ME concentration of the experimental diets did not affect the concentrations of water, fat, ash and protein concentration in the animal body (P>0.05) when expressed in g/kg EBW (Table 3). The empty body fat and energy contents were calculated using the equations presented in Table 4. Table 5 shows that there was a considerable increase of 31.85 and 21.00% in the fat and energy content of the EBW of animals when BW increased from 13 to 28.70 kg. This behaviour can be explained considering that concentrate increase in the diet, or soluble carbohydrates and rapid fermentation, favour microbial access to nutrients, thereby increasing the rate of fermentation and the production of volatile fatty acids in the rumen. Thus, the acetate – which is the main volatile fatty acid produced (albeit in high concentrate diets) and the main precursor of lipogenesis in adipose tissue – causes greater deposition of fat in the empty body of the animal. It is accepted that 90% of butyrate, propionate and half of 30% of the produced acetate are used to meet the energy needs of the gastrointestinal tract (Bergman, 1990). Thus, higher concentration of acetate reaches the portal circulation, which is intended for the energy metabolism of peripheral tissues, since it is little metabolized by the liver unlike propionate and butyrate. Moreover, high concentrate inclusion also implies increased demand for amino acids and peptides as a nitrogen source for the growth of microorganisms responsible for the degradation of non-fibre

Table 2. Mean values of parameters for body weight, performance, intake and energy retention of Brazilian Somali ram lambs.

| Parameter | ME levels, MJ/kg DM | SEM | L | Q |
|-----------|---------------------|-----|---|---|
| IBW, kg   | 12.44               | 13.62 | 13.70 | 13.60 | 13.69 | - | - | - |
| FBW, kg   | 15.73               | 21.70 | 24.23 | 28.71 | 26.49 | 0.878 | <0.001 | <0.001 |
| SBW, kg   | 15.14               | 20.96 | 23.68 | 28.10 | 25.99 | 0.869 | <0.001 | <0.001 |
| EBW, kg   | 11.55               | 17.09 | 20.30 | 24.54 | 22.89 | 0.848 | <0.001 | <0.001 |
| ADG, g/day| 34.23               | 73.74 | 101.24 | 150.84 | 126.40 | 22.72 | <0.001 | 0.715 |
| EBW gain, g/day | 19.83               | 62.04 | 94.42 | 139.00 | 120.53 | 27.81 | <0.001 | 0.522 |
| DM intake, g/EBW<sup>0.75</sup> day | 53.58               | 71.28 | 77.14 | 76.93 | 70.56 | 1.271 | <0.001 | <0.001 |
| ME intake,kJ/EBW<sup>0.75</sup> day | 523.63              | 895.02 | 1005.29 | 1074.26 | 1146.83 | 5.241 | <0.001 | <0.001 |
| Daily retained energy, kJ/EBW<sup>0.75</sup> day | 63.16              | 186.34 | 208.54 | 226.22 | 259.28 | 8.608 | <0.001 | <0.001 |
| Heat production, kJ/EBW<sup>0.75</sup> day | 460.47              | 708.68 | 795.75 | 851.34 | 887.54 | 1.417 | <0.001 | <0.001 |

ME, metabolizable energy; DM, dry matter; L, linear; Q, quadratic; IBW, initial body weight; FBW, final body weight; SBW, shrunk body weight; EBW, empty body weight; ADG, average daily gain. Reference values for body weight: IBW=13.53; FBW=13.53; SBW=13.00; EBW=10.44. °Days to slaughter for each ME level (in parenthesis): - (4.93); 104 (8.65); 103 (9.41); 101 (10.12); 102 (11.24).

Table 3. Chemical composition of the empty body of Brazilian Somali ram lambs.

| Parameter, g/kg EBW | Reference value | ME levels, MJ/kg DM | SEM | L | Q |
|---------------------|-----------------|---------------------|-----|---|---|
| Water               | 586.25          | 591.34              | 559.06 | 561.15 | 524.315 | 56.70 | 2.26 | 0.628 | 0.520 |
| Fat                 | 158.81          | 214.67              | 241.38 | 250.95 | 285.13 | 250.49 | 3.12 | 0.739 | 0.636 |
| Protein             | 188.98          | 186.76              | 196.48 | 193.50 | 190.21 | 189.24 | 0.32 | 0.198 | 0.187 |
| Ash                 | 63.95           | 45.28               | 41.88 | 35.37 | 23.76 | 38.46 | 1.03 | 0.809 | 0.729 |

EBW, empty body weight; ME, metabolizable energy; DM, dry matter; L, linear; Q, quadratic.
carbohydrates resulting in lower exhaust dietary amino acids to the small intestine, thus decreasing the concentration of protein retained in the hollow body.

After deriving logarithmic equations for the prediction of fat and energy as a function of EBW (Table 6), we determined the NE requirement and quantity of fat deposited in the EBW. The NE requirement increased with increasing BW, due to a parallel increase in the quantity of fat deposited per kg gained. The values obtained ranged from 55.276 to 68.588 MJ/kg EBWG for weights from 13 to 28.70 kg BW, respectively. The NE requirement increased with increasing body weight (from 0.14 to 0.18 MJ/animal.day\(^{-1}\) for body weights from 13 to 28.70 kg) and daily gains of 100 g (Table 7).

Energy required for maintenance is the amount of energy used in basal metabolism and lost as heat when an animal is fasting (also known as fasting HP) plus the heat of activity and the additional energy lost when an animal consumes enough feed to maintain a static body energy content (heat increment at zero energy balance; National Research Council, 1985). The value obtained for net energy for maintenance (NE\(_{m}\)) in the present study (239.77 kJ/kg\(^{0.75}\) BW/day) was similar to the values reported by Gonzaga Neto et al. (2005) and Regadas Filho et al. (2013), e.g., 219.41 and 212.01 kJ/kg\(^{0.75}\) BW/day, respectively. The NE\(_{m}\) value obtained in this study was similar to that recommended by the National Research Council (1985) (243.08 kJ/kg\(^{0.75}\)EBW/day), 9.86% lower than the value suggested by ARC (1980) and 16.95% below that recommended by the CSIRO (2007). Differences in NE\(_{m}\) estimates may be expected when different energy systems are used, principally because of variations in the nature of the experimental data (from comparative slaughter trials, from energy balances calculated using respiration chambers, or from feeding trials; Cunha et al. (2010). Such differences also arise because accurate quantification of the energy requirements of immature animals is impaired by the collinearity and interdependency of maintenance and growth and by variations in the partial efficiency values km and kg. Generally, Somali sheep are considered adapted to extensive production systems. Therefore, our data agree with others, showing that NE\(_{m}\) is influenced by the genetic potential for performance traits. One reason for this relationship may be a larger mass of metabolically active organs, such as the gastrointestinal tract, in animals with a greater potential for productivity. Luo et al. (2004) reported a greater variability in estimates of the maintenance requirement for ME (MRME) than those of maintenance requirement for NE (MRNE), which is expected given higher levels of feeding for direct determination of MRME and greater differences among diets in efficiency of ME utilization for gain than maintenance. Therefore, differences in MRME among genotypes might depend on variations in MRNE or km, although dietary characteristics may affect MRNE and km. Garrett (1980) reported that the maintenance energy requirements involves the amount of energy necessary to achieve an equilibrium state and would include the cost of any minimal muscular activities necessary to obtain and process sufficient energy sources to provide the requisite number of calories. This statement assumes that maintenance requirements are fixed, independent of age or level of gain. However, Frisch and Vercoe (1977) have indicated that maintenance requirements might vary in different rates of gain and other

### Table 4. Logarithmic equations to estimate fat and energy body contents and composition of Brazilian Somali ram lambs.

| Parameter | Regression equation | \(r^2\) | RMSE | \(P\) |
|-----------|---------------------|------|------|-----|
| Fat, g    | \(\log_{10} \text{fat}=1.964 (0.113)+1.337 (0.088) \log_{10} \text{EBW}\) | 0.87 | 0.05 | 0.001 |
| Energy, MJ| \(\log_{10} \text{energy}=0.804 (0.173)+1.233 (0.085) \log_{10} \text{EBW}\) | 0.97 | 0.12 | 0.001 |

RMSE, root mean square error; EBW, empty body weight.

### Table 5. Estimates of the fat and energy contents at different body weight intervals in growing Brazilian Somali ram lambs in function of empty body weight.

| BW, kg | EBW, kg | Fat, g/kg EBWG\(^#\) | Energy, MJ/kg EBWG\(^§\) |
|--------|---------|----------------------|-------------------------|
| 13.00  | 9.38    | 195.89               | 44.846                  |
| 20.00  | 16.07   | 234.91               | 50.829                  |
| 25.00  | 20.85   | 256.47               | 54.003                  |
| 28.70  | 23.72   | 267.86               | 55.646                  |

BW, body weight; EBW, empty body weight. EBW=3.048+0.956 BW.

### Table 6. Regression equations to predict the contents of fat and net energy requirement for kg of empty body weight gain at different body weight intervals in Brazilian Somali ram lambs.

| BW, kg | EBW, kg\(^2\) | Fat, g/kg EBWG\(^3\) | Energy, MJ/kg EBWG\(^3\) |
|--------|---------------|---------------------|-------------------------|
| 13.00  | 9.38          | 261.91              | 55.276                  |
| 20.00  | 16.07         | 314.13              | 62.652                  |
| 25.00  | 20.85         | 342.96              | 66.563                  |
| 28.70  | 23.72         | 358.19              | 68.588                  |

BW, body weight, EBW, empty body weight; EBWG, empty body weight gain. *EBW=3.048+0.956 BW; \(Y=123.128 \times \text{EBW}^{0.337}\); \(Y=7.857 \times \text{EBW}^{0.232}\).

### Table 7. Net requirements of energy for body weight gain in Brazilian Somali lambs.

| BW, kg | Daily gain, g |
|--------|---------------|
|        | 100           | 150           | 200           | 250           | 300           |
|        | Energy, MJ/animal/day |
| 13.00  | 0.93          | 1.39          | 1.85          | 2.31          | 2.78          |
| 20.00  | 1.00          | 1.51          | 2.01          | 2.51          | 3.01          |
| 25.00  | 1.07          | 1.60          | 2.13          | 2.67          | 3.20          |
| 28.70  | 1.10          | 1.65          | 2.20          | 2.75          | 3.30          |

BW, body weight.
studies have indicated the influence of EBG on efficiency of use of ME to NEm (Garrett, 1980; Vermorel and Bickel, 1980; Garrett and Johnson, 1983). The variability in NEm estimates might be attributable partly to differences in the mathematical models used and the accuracy of the measurements made (Tedeschi et al., 2004). The NE required for maintenance is also influenced by the physiological conditions, age, gender, physical activity and temperature (National Research Council, 2000, 2007) and is further influenced by body composition because metabolic activity is more intense in muscular tissue than in adipose tissue (Garrett, 1980). It is estimated that 50% of the maintenance energy requirement is consumed in protein recycling and transporting ions through the membranes (Baldwin et al., 1980).

The equation and NE requirements for weight gain for different ranges of body weight are shown in Tables 6 and 7, respectively. In weight gain for different ranges of body weight EBWG, respectively, representing an increase of 38.02%. Considering that fat contains, on average, twice the energy contained in the carbohydrates and proteins, increasing it proportionately in the carcass of the animal promotes an increase in the body energy retention and, consequently, the energy requirements.

The NEg values obtained in our study were less to those reported by the National Research Council (2007) for late maturing lambs. For example, lambs with 20 kg of EBW and ADG ranging from 100 to 200 g had NEg ranging from 0.21 to 0.42 Mcal/day (National Research Council, 2007), respectively. For lambs with 20 kg of BW (100 g/day) in our study was 28.57% less than the predicted value estimated by the National Research Council (2007). The requirements for growth suggested by the National Research Council in 1985 are 0.3 Mcal/day for animals 20 kg with ADG of 100 g/day. For lambs with 20 kg BW, the values predicted by the ARC (1980) and ARFC (1993) are 1.482 Mcal/day and 1.386 Mcal/day for ADG of 100 g/day, respectively. These values are higher than those found in the present study. These requirements of our study will be most useful for lambs of the same age, managed under similar conditions and environment, deposition gains of a comparable composition.

The slaughter weight of Brazilian Somali sheep ranges from 28 to 35 kg BW in Brazil’s semiarid areas. We believe that reduction of this slaughter weight could increase the sheep’s economic efficiency. Furthermore, a reduced slaughter weight may provide better heat dissipation due to the greater surface area (Silanikove, 2000), as these animals are subjected to conditions of heat stress (Regadas Filho et al., 2013). The NE stored per kg of live weight gain varies with the age and sex of the animal and with the rate of gain because the proportion of fat, protein and water in the gain varies. In young animals, a lower proportion of the gain is fat and a higher proportion is protein and water than in older animals. At higher rates of gain, more of the gain is fat.

The ability to predict live weight gain is important in the preparation of diets for meat sheep being grown for sale, in the prediction of rates of gain in the supplementation of sheep on inadequate foraging, particularly meat-pro- producing breeds, live weight gain is an opportunistic response to good feed conditions rather than a result of a deliberate attempt to increase body weight. While not formally predicted by wool producers, live weight gains in hair sheep producing flocks are still essential components of normal sheep management to enable the growth of young animals, the recovery of lost live weight of lambs growing and the development of body reserves to provide nutrition when feed conditions deteriorate (Abbott and Maxwell, 2002). Rates of protein deposition increase at decreasing rates, whereas rates of fat deposition increase at increasing rates with the rate of gain.

Conclusions

In conclusion, our study indicated that the NE requirements for maintenance in Brazilian Somali lambs were similar to the values commonly recommended by the United States’ nutritional system, but lower than those recommended by the Agricultural Research Council and Commonwealth Scientific and Industrial Research Organization. Net requirements for weight gain were lower than the values commonly recommended by nutritional system of the United States.

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