Small Ruminant Research 98 (2011) 93–97

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Prediction of intake and average daily gain by different feeding systems for goats

Izabelle Auxiliadora Molina de Almeida Teixeira[a,*,1], Normand St-Pierre[b], Kleber Tomás de Resende[a,1], Antonello Cannas[c]

[a] Departamento de Zootecnia, Universidade Estadual Paulista/UNESP, Jaboticabal, São Paulo 14884-900, Brazil
[b] Department of Animal Sciences, The Ohio State University, Columbus, OH 43210, USA
[c] Dipartimento di Scienze Zootecniche, Università di Sassari, Sassari 07100, Italy

ARTICLE INFO

Article history:
Available online 9 April 2011

Keywords:
Average daily gain
Dry matter intake
Goat kids
Nutrition models
Nutritional requirements

ABSTRACT

A main purpose of a mathematical nutrition model (a.k.a., feeding systems) is to provide a mathematical approach for determining the amount and composition of the diet necessary for a certain level of animal productive performance. Therefore, feeding systems should be able to predict voluntary feed intake and to partition nutrients into different productive functions and performances. In the last decades, several feeding systems for goats have been developed. The objective of this paper is to compare and evaluate the main goat feeding systems (AFRC, CSIRO, NRC, and SRNS), using data of individual growing goat kids from seven studies conducted in Brazil. The feeding systems were evaluated by regressing the residuals (observed minus predicted) on the predicted values centered on their means. The comparisons showed that these systems differ in their approach for estimating dry matter intake (DMI) and energy requirements for growing goats. The AFRC system was the most accurate for predicting DMI (mean bias = 91 g/d, $P < 0.001$; linear bias 0.874). The average ADG accounted for a large part of the bias in the prediction of DMI by CSIRO, NRC, and, mainly, AFRC systems. The CSIRO model gave the most accurate predictions of ADG when observed DMI was used as input in the models (mean bias 12 g/d, $P < 0.001$; linear bias −0.229), while the AFRC was the most accurate when predicted DMI was used (mean bias 8 g/d, $P > 0.1$; linear bias −0.347).

1. Introduction

In the last decades several feeding systems for goats have been published: (i) the Institut National de la Recherche Agronomique (INRA, 2007; INRA); (ii) the Commonwealth Scientific and Industrial Research Organization (CSIRO, 2007; CSIRO); (iii) the Agricultural and Food Research Council (AFRC, 1998; AFRC); (iv) the Estación Experimental del Zaidin, Granada (Aguilera, 2001); (v) the recommendations for the supply of energy and nutrients to goats (Drochner et al., 2003); (vi) the E (Kika) de la Garza Institute for Goat Research-Langston University (Sahlu et al., 2004; IGR); (vii) the National Research Council (NRC, 2007; NRC); and (viii) the Small Ruminant Nutrition System (Cannas et al., 2008; Tedeschi et al., 2008; SRNS). Among them, the most widely used are AFRC, CSIRO, SRNS, NRC and INRA, but they have not been compared in the literature. The AFRC system deals with dairy breeds only and uses a simplified approach, based mainly on ARC (1980), deriving many of its equations from the system developed for sheep and cattle. The CSIRO system based most of its recommendation on the models developed for sheep. In the SRNS, energy requirements are predicted based on the

* Corresponding author. Tel.: +55 16 32092682; fax: +55 16 32092682.
E-mail address: izabelle@fcav.unesp.br (I.A.M.d.A. Teixeira).
[1] CNPq/INCT-CA member.

0921-4488/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.smallrumres.2011.03.024

Table 1
Information regarding the studies used in the comparison of the feeding systems.

Study	Reference	*n*	Genotype	Animal type	Gender	Type of diet	Feeding treatment
1	Teixeira et al. (2006)	21	1/2 Boer, 1/2 Saanen	Meat	Male	Weaned	Ad libitum, or with 30% and 60% feed restriction
2	Teixeira (2004)	18	1/2 Boer, 1/2 Saanen	Meat	Male	Unweaned in part of the trial	Ad libitum, or with 30% and 60% feed restriction
3	Medeiros (2001)	27	Saanen	Dairy	Male	Unweaned in part of the trial	Ad libitum, or with 30% and 60% feed restriction
4	Ferreira (2003)	27	Saanen	Dairy	Castrated	Weaned	Ad libitum, or with 30% and 60% feed restriction
5	Fernandes et al. (2007)	21	3/4 Boer, 1/4 Saanen	Meat	Male	Weaned	Ad libitum, or with 30% and 60% feed restriction
6	Resende (1989)	12	1/2 local, 1/2 dairy breed	Local	Male	Unweaned in part of the trial	Ad libitum or at 1.2 × maintenance
7	Ribeiro (1995)	11	1/2 local, 1/2 dairy breed	Local	Male	Unweaned in part of the trial	Ad libitum or at 1.2 × maintenance

SRNS for sheep, modified to account for specific requirements of goats, whereas its growth model is based, with some modifications, on CSIRO (2007). The NRC system adopted almost totally the IGR system, which reported the requirements of Angora and dairy, meat and indigenous breeds separately, however regarding feed intake NRC adopted the model suggested by CSIRO. The INRA system was specifically developed for dairy goats, but its equations have not been published nor can be derived, and its predictions are available only in tabular form.

The goal of this paper was to compare and evaluate the main goat feeding systems that have published their equations (AFRC, CSIRO, SRNS and NRC), focusing on their estimates of dry matter intake and average daily gain of goat kids of different breeds or crossbreds.

2. Material and methods

The goat feeding systems compared and evaluated in this study were AFRC, CSIRO, NRC and SRNS. To evaluate them, results from seven studies carried out at UNESP (Jaboticabal, Brazil) and UFV (Viçosa; Brazil) with confined growing goat kids were used, because individual measurements of intake, digestibility, ME intake and body composition (based on comparative slaughtering) were available. These studies provided almost all inputs required by AFRC, CSIRO, NRC and SRNS systems for the prediction of dry matter intake (DMI, g/d) and average daily gain (ADG, g/d). All studies used a dry diet with roughage to concentrate ratio of approximately 50:50; studies 2, 3, 6 and 7 also used a liquid diet made of milk (Table 1). The main characteristics of each study are presented in Table 1, whereas the main inputs needed for the systems are reported in Table 2.

Dry matter intake is predicted by all evaluated systems except for the SRNS, because this system adopted the DMI model suggested by the AFRC system. In the systems evaluated, DMI is predicted considering starting values that are adjusted on the basis of ME concentration in the diet (AFRC, Eq. (1)), utilization of milk diets (CSIRO, Eq. (2)), or quality constraint based on digestibility (NRC, Eq. (3)). The predictions of DMI were compared using exclusively the data from kids fed ad libitum (67 observations in total).

$$\text{DMI (g/d)} = (76.7 \times \text{BW}^{0.75}) \times (-0.666 + 1.333 \times \text{ME} - 0.266 \times \text{ME}^2) \quad (1)$$

$$\text{DMI (kg/d)} = 0.04 \times \text{SRW} \times \left(\frac{N}{\text{SRW}}\right) \times \left(1.7 - \frac{N}{\text{SRW}}\right) \times \left[\frac{(1 - P_{\text{milk}})}{(1 + \exp^{(-0.5(\text{age}-25))})}\right] \quad (2)$$

$$\text{DMI (kg/d)} = 0.04 \times \text{SRW} \times \left(\frac{N}{\text{SRW}}\right) \times \left(1.7 - \frac{N}{\text{SRW}}\right) \times [(1 - 1.7 \times (0.8 - \text{Dig}] \quad (3)$$

where $\text{BW}^{0.75}$ is metabolic body weight (kg); ME the metabolizable energy of diet (Mcal/kg DM); SRW is standard reference weight (kg); N is normal weight (kg); P_{milk} is proportion of the diet from milk; and Dig the digestibility of the diet.

For the comparisons of ADG, all animals were used ($n = 137$) and ADG predictions were made using (a) the DMI predicted by the models or (b) the DMI observed for each animal, in order to verify if the models work better with the actual intake than with the predicted intake. Similarly, the CSIRO and SRNS evaluations were also done using observed or predicted energy retained (ER). Because data of body condition score and daily temperature were available for only 3 studies (1, 2 and 5; Table 1), corrections for these factors were not made in the systems that account for them. Also, the SRNS suggested a correction to the cost of urea excretion based on the sum of nitrogen in excess in the rumen, which could not be estimated because it requires information not available in the considered studies. For NRC the different genotypes in the studies were considered according to Table 1, and then meat genotype was considered in 3 studies, dairy genotype in 2 studies and indigenous in 2 studies.

The feeding systems were evaluated by regressing residual (observed minus predicted) values on the predicted values centered on their mean values (St-Pierre, 2003). This makes the slope and intercept estimates in the regression orthogonal and, thus, independent. The intercepts of the regression equations were used to estimate mean biases, whereas linear biases were assessed using the slopes of the regression equations.

3. Results and discussion

3.1. Estimation of dry matter intake

Statistics of the relationships between residuals and predicted DMI for the AFRC, CSIRO and NRC feeding systems showed that the basic equations for predicting DMI recommended by all feeding systems were not accurate (evaluations 1, 3, 5; Table 3). On an average, the AFRC underpredicted DMI by 92 g/d, whereas NRC and CSIRO overpredicted DMI by more than 330 g/d. Results also showed an absence of linear bias for the last two systems (i.e., the magnitude of the bias does not change with the magnitude of the prediction). When the adjustments suggested by the systems were applied no marked improvements were achieved in the prediction (evalua-

Table 2
Descriptive statistics of the inputs taken from the studies described in Table 1 used in the comparison of the feeding systems.

	Mean	S.D.	Minimum	Maximum
Age (d)	92.0	38.5	28.0	158.0
Average daily gain (g/d)	119.8	78.6	−19.0	390.9
Birth weight (kg)	3.63	0.76	1.95	5.60
$BW^{0.75}$ (kg)	7.85	2.78	3.17	12.26
Dry matter intake (g/d)	521	327	45	1306
Energy retained (kcal/d)	215.4	192.0	−78.8	745.8
Mature body weight (kg)	90.2	12.2	72.5	105.3
Metabolizable energy of the diet (kcal/kg DM)	2581	212	2277	2975
Metabolizable energy intake (kcal/d)	1432	782	277	3318
Metabolizability (GE/ME)	0.71	0.10	0.58	0.96
Milk in the diet (% of ME intake)	40.4	21.9	12.8	99.6

tions 2, 4, 6; Table 3). For NRC and CSIRO, a decrease in the mean bias was observed (−162 and −255 g/d, respectively). On the other hand, significant linear biases ($P < 0.05$) were found. The adjustment for energy density in the diet suggested by AFRC resulted in slight changes in the DMI prediction (mean bias = 91 g/d, $P < 0.001$; Table 3).

Mature body weight and ADG were tested as covariates in models for predicting DMI. Considering mature body weight as a covariate in DMI prediction, an absence of linear bias was observed for NRC ($P = 0.34$ and $P = 0.90$, for DMI and DMI adjusted, respectively) and CSIRO ($P = 0.34$ and $P = 0.97$, for DMI and DMI adjusted, respectively) predictions, confirming that these systems account correctly for this variable. On the other hand, for the AFRC predictions significant linear biases were found ($P = 0.02$), with increasing bias with greater body weight. Highly significant linear bias ($P < 0.01$) occurred when ADG was considered as a covariate, indicating that ADG should be considered in DMI prediction for growing animals. This was particularly true for AFRC (linear bias = 2.883), in which the greater the ADG the worst was the prediction. As a result, AFRC can be greatly improved if ADG is considered in the model of DMI prediction. Because previous studies have reported that animal performances can be used for predicting intake, many models have considered daily gain, directly or indirectly, for predicting DMI in growing cattle (Mertens, 1987; NRC, 2000, 2001).

The maximum voluntary feed intake is determined by the interaction of energy requirement and physical capacity of the digestive tract, and these parameters are clearly related to animal size. However, the animal mass *per se* is not strictly related with body size, because the latter is influenced by development stage and body condition. In addition, potential dry matter intake of the individual is affected by physiological stage and amount and composition of the offered diet. However, not all these factors are taken into consideration by the feeding systems.

3.2. Estimation of average daily gain

Results of the regression of residual ADG on predicted ADG centered on their mean predictions are presented in Table 4. In general, all models presented a significant ($P < 0.01$) linear and mean bias, except for AFRC (mean bias = −8 g/d, $P > 0.10$; evaluation 2 in Table 4).

The predictions obtained when observed DMI was used as an input and ER was predicted by each feeding system (evaluations 1, 3, 7, and 9 for the systems AFRC, CSIRO, NRC, and SRNS, respectively) represent the intrinsic ability of each system to predict ADG when nutrient supply is known. In this case, the CSIRO model gave the most accurate predictions, with slightly greater mean bias than the AFRC (12 vs. −10 g/d for CSIRO and AFRC, respectively) but lower linear bias (−0.229 vs. −0.317) and smaller bias over the full range of the predicted values (from 45 to −52 vs. from 41 to −102 g/d). The SRNS predicted ADG with greater mean bias (19 g/d, $P < 0.001$) than the AFRC but lower linear bias (−0.285, $P < 0.001$), which resulted in a maximum

Table 3
Statistics from regressions of residual dry matter intake (DMI) on DMI predicted by AFRC, CSIRO and NRC centered on their mean value. The SNRS is not considered because it does not predict DMI.

Evaluation number and model	Adj[a]	Mean bias[b]		Linear bias[c]		Residual SE (g/d)	Bias at minimum predicted DMI (g/d)	Bias at maximum predicted DMI (g/d)
		Estimate (g/d)	P	Estimate	P			
1. AFRC	No	92.0	<0.001	0.885	<0.001	189	−201.6	306.8
2. AFRC	Yes	91.5	<0.001	0.874	<0.001	192	−197.3	307.8
3. CSIRO	No	−336.9	<0.001	0.029	0.650	185	−354.7	−322.5
4. CSIRO	Yes	−254.6	<0.001	−0.206	<0.001	182	−39.5	−372.4
5. NRC	No	−336.9	<0.001	0.029	0.650	185	−354.7	−322.5
6. NRC	Yes	−162.0	<0.001	0.175	0.030	195	−246.7	−79.6

[a] Adj = adjustments, AFRC adjustment was based on metabolizable energy in the diet (AFRC, 1998, p. 34), CSIRO adjustment was based on proportion of the diet from milk (CSIRO, 2007, p. 211) and NRC adjustment was based on quality constraint of the diet (NRC, 2007, p. 34).

[b] Mean bias is estimated as the intercept of the regression of the residuals (observed–predicted) on the predicted values centered at their means.

[c] Linear bias is estimated by the slope of the regression of the residuals (observed–predicted) on the predicted values. It represents the change in the bias of the prediction (g/d) per unit change in the prediction (i.e., per g/d in predicted DMI). Therefore, it is unitless.

Table 4
Statistics from regressions of residual average daily gain (ADG) on ADG predicted by AFRC, CSIRO, NRC and SRNS centered on their mean value.

Evaluation number and model	DMI[a]	ER[b]	Mean bias[c]		Linear bias[d]		Residual SE (g/d)	Bias at minimum predicted ADG (g/d)	Bias at maximum predicted ADG (g/d)
			Estimate (g/d)	*P*	Estimate	*P*			
1. AFRC	Obs	Pred	−9.7	<0.001	−0.317	<0.001	33.5	41.0	−101.9
2. AFRC	Pred	Pred	−7.9	0.192	−0.347	0.003	70.6	61.4	−36.7
3. CSIRO	Obs	Pred	11.6	<0.001	−0.229	<0.001	37.9	44.9	−52.1
4. CSIRO	Obs	Obs	36.0	<0.001	−0.038	0.502	44.6	40.4	27.8
5. CSIRO	Pred	Pred	−94.4	<0.001	−0.843	<0.001	75.5	150.1	−302.5
6. CSIRO	Pred	Obs	37.5	<0.001	−0.022	0.697	44.3	40.0	32.6
7. NRC	Obs	Pred	33.0	<0.001	−0.325	<0.001	39.3	78.5	−60.0
8. NRC	Pred	Pred	−122.0	<0.001	−0.825	<0.001	75.5	160.5	−342.0
9. SRNS	Obs	Pred	19.5	<0.001	−0.285	<0.001	42.8	58.1	−57.4
10. SRNS	Obs	Obs	28.1	<0.001	−0.131	0.02	46.6	45.1	−5.1

[a] DMI = dry matter intake, where Obs = observed and Pred = predicted by the model.
[b] ER = energy retained, where Obs = observed and Pred = predicted by the model.
[c] Mean bias is estimated as the intercept of the regression of the residuals (observed–predicted) on the predicted values centered at their means.
[d] Linear bias is estimated by the slope of the regression of the residuals (observed–predicted) on the predicted values. It represents the change in the bias of the prediction (g/d) per unit change in the prediction (i.e., per g/d in predicted DMI). Therefore, it is unitless.

Table 5
Statistics on the bias of the average daily gain (ADG), classified on the basis of animal type, growth stage and feed restrictions, as predicted by AFRC, CSIRO, NRC and SRNS systems.

Effect	Level	AFRC		CSIRO		NRC		SRNS	
		Bias (g/d)	*P*	Bias (g/d)	*P*	Bias (g/d)	*P*	Bias (g/d)	*P*
Animal type	Meat	−25.0	<0.001	−5.8	0.27	9.7	0.11	−1.7	0.77
	Dairy	4.0	0.51	27.4	<0.001	56.0	<0.001	43.5	<0.001
	Local	−3.0	0.75	20.0	0.02	39.0	<0.001	18.4	0.06
Growth stage	Unweaned	−6.0	0.33	29.7	<0.001	64.0	<0.001	49.6	<0.001
	Weaned	−14.0	0.02	−6.2	0.19	5.0	0.65	−10.3	0.04
Feed restriction	Ad libitum	−39.0	<0.001	3.6	0.55	13.0	0.070	12.2	0.09
	30% restr.	1.0	0.89	20.6	0.01	46.0	<0.001	28.6	0.001
	60% restr.	9.0	0.17	8.3	0.24	42.0	<0.001	20.5	0.02
	Maint. + 20%	21.0	0.09	25.8	0.04	46.0	<0.001	17.0	0.24

bias of 58 g/d over the full range of the predicted values. The NRC model gave the worst results for mean (33 g/d, $P < 0.001$) and linear bias (−0.325, $P < 0.001$) and the second worst after AFRC for the maximum bias over the full range of the predicted values (78 g/d).

When predicted instead of measured DMI was used as an input (evaluations 2, 5, and 8 for the systems AFRC, CSIRO, NRC, respectively; the SRNS was not evaluated), the AFRC gave the most accurate predictions due to its high accuracy in predicting DMI, as previously discussed.

When measured ER was used as an input in the CSIRO and SRNS models (evaluations 4 and 10), the mean bias was slightly increased. For CSIRO the linear bias was not statically significant. For SRNS, although the linear bias was significant statistically ($P < 0.02$) the maximum bias over the full range of the predicted values was substantially decreased.

Age, body weight, mature body weight, fat and protein gain were tested as covariate in the ADG prediction and the results showed no significant linear bias ($P > 0.05$; data no reported) for protein gain in the CSIRO and SRNS. The results regarding age as covariate showed a significant linear bias ($P < 0.01$; data not reported) for all except for AFRC system, being in all cases the younger the animal the greater the bias.

Overall, AFRC estimated accurately the ADG of growing goats. By evaluating the effect of class variables on the residuals, this system was less accurate in estimating the ADG of meat breeds, weaned kids and ad libitum fed kids compared to the other classes (Table 5). This is probably related to the fact that this system was developed for dairy animals. On the other hand, the CSIRO, NRC and SRNS systems had the greatest bias in the case of dairy breeds, unweaned kids and kids subjected to feed restriction. In particular, both the NRC and the SNRS, the only systems to account for the breed genotype class, markedly underpredicted the ADG of kids of dairy breeds (bias of 56 and 43 g/d for the NRC and SRNS systems, respectively; Table 5), probably because both of them consider substantially greater maintenance requirements for dairy than for other breeds. In addition, the NRC had the highest bias among the systems for kids under feed restriction (estimates were underpredicting by more than 40 g/d) and for pre-weaning kids (mean bias of 64 g/d).

4. Conclusions

The comparisons based on the dataset of Brazilian studies showed that the AFRC was the most accurate system for predicting DMI and that the average ADG of kids accounted for the greatest part of the bias in the prediction of DMI by CSIRO, NRC, and, mainly, AFRC systems. The CSIRO model gave the most accurate predictions of ADG when observed DMI was used, while the AFRC was the most accurate when predicted DMI was used.

Conflict of interest statement

None declared.

Acknowledgements

We are grateful to Ana H.D. Francesconi for the technical and linguistic revision.

We would like to thank Fundação de Amparo a Pesquisa do Estado de Sao Paulo/FAPESP for provision of financial support.

References

AFRC, 1998. The Nutrition of Goats. Technical Committee on Response to Nutrients. Report number 10. CAB International, Wallingford, UK.

Aguilera, J.F., 2001. Aportaciones al conocimiento de la nutrición energética de pequeños rumiantes, con particular referencia al ganado caprino. Arch. Zootec. 50, 565–596.

ARC, 1980. The Nutrient Requirements of Ruminant Livestock. Tech. Rev. Agric. Res. Council Working Party. Commonwealth Agricultural Bureaux, Farnham Royal, UK.

Cannas, A., Atzori, A.S., Boe, F., Teixeira, I.A.M.A., 2008. Energy and protein requirements of goats. In: Cannas, A., Pulina, G. (Eds.), Dairy Goats, Feeding and Nutrition. CABI, Cambridge, pp. 118–146.

CSIRO, 2007. Nutrient Requirements of Domesticated Ruminants. Commonwealth Scientific and Industrial Research Organization, Collingwood, VIC.

Drochner, W., Flachowsky, G., Pallauf, J., Pfeffer, E., Rodehutscond, M., Staudacher, W., 2003. Recommendations for the Supply of Energy and Nutrients to Goats. DLG-Verlag, Frankfurt, Germany.

Fernandes, M.H.M.R., Resende, K.T., Tedeschi, L.O., Fernandes Jr., J.S., Silva, H.M., Carstens, G.E., Berchielli, T.T., Teixeira, I.A.M.A., Akinaga, L., 2007. Energy and protein requirements for maintenance and growth of Boer crossbred kids. J. Anim. Sci. 85, 1014–1023.

Ferreira, A.C.D., 2003. Composição corporal e exigências nutricionais em proteína, energia e macrominerais de caprinos Saanen em crescimento. Ph.D. dissertation, Universidade Estadual Paulista, Jaboticabal, SP, Brazil.

INRA, 2007. Alimentation des bovins, ovins et caprins. Besoins des animaux. Valeurs des aliments. Tables INRA 2007. Editions Quae, Versailles, France.

Medeiros, A.N., 2001. Composição corporal e exigências nutricionais em proteína e energia para caprinos Saanen na fase inicial de crescimento. Ph.D. dissertation, Universidade Estadual Paulista, Jaboticabal, SP, Brazil.

Mertens, D.R., 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64, 1548–1558.

NRC, 2000. Nutrient Requirements of Beef Cattle, Update 2000. National Academy Press, Washington, DC.

NRC, 2001. Nutrient Requirements of Dairy Cattle, 7th revised edition. National Academy Press, Washington, DC.

NRC, 2007. Nutrient Requirements of Small Ruminants. Sheep, Goats, Cervids and New World Camelids. National Academy Press, Washington, DC.

Resende, K.T., 1989. Métodos de estimativa da composição corporal e exigências nutricionais de proteína, energia e macrelementos inorgânicos de caprinos em crescimento. Ph.D. dissertation, Universidade Federal de Viçosa, Viçosa, MG, Brazil.

Ribeiro, S.D.A., 1995. Composição corporal e exigências em energia, proteína e macrominerais de caprinos mestiços em fase inicial de crescimento. M.Sc. thesis, Universidade Estadual Paulista, Jaboticabal, SP, Brazil.

Sahlu, T., Goetsch, A.L., Luo, J., Nsahlai, I.V., Moore, J.E., Galyean, M.L., Owens, F.N., Ferrell, C.L., Johnson, Z.B., 2004. Nutrient requirements of goats: developed equations, other considerations and future research to improve them. Small Rumin. Res. 53, 191–219.

St-Pierre, N.R., 2003. Reassessment of biases in predicted nitrogen flows to the duodenum by NRC 2001. J. Anim. Sci. 86, 344–350.

Tedeschi, L.O., Cannas, A., Fox, D.G., 2008. A nutrition mathematical model to account for dietary supply and requirements of energy and nutrients for domesticated small ruminants: the development and evaluation of the Small Ruminant Nutrition System. R. Bras. Zootec. 37, 179–190.

Teixeira, I.A.M.A., 2004. Métodos de estimativa de composição corporal e exigências nutricionais de cabritos F1 Boer × Saanen. Ph.D. dissertation, Universidade Estadual Paulista, Jaboticabal, SP, Brazil.

Teixeira, I.A.M.A., Pereira Filho, J.M., Murray, P.J., Resende, K.T., Ferreira, A.C.D., Fregadolli, F.L., 2006. Water balance in goats subjected to feed restriction. Small Rumin. Res. 63, 20–27.