Replacement of soybean meal with maize steep liquor in the diets of feedlot lambs

A.P.D. de Freitas, M.deA. Ferreira, J.P.F. de Oliveira, Á.E.M. da Silva, L.F.P. Soares, J.deL. Silva[#], L.E. Salla & A.R.D.L. Souza

Department of Animal Science, Federal Rural University of Pernambuco, Dom Manoel de Medeiros Street, s/n, Dois Irmãos – Zip Code: 52171-900 - Recife/PE, Brazil

(Received 16 July 2014; Accepted 8 October 2015; First published online 14 December 2015)

Abstract

It was hypothesized that maize steep liquor, which is high in crude protein, could replace soybean meal in supplementation strategies in lamb production systems. Therefore, the effects of replacing soybean meal with maize steep liquor at 0%, 33%, 66% and 100% on a dry matter (DM) basis on growth performance, nutrient digestibility and carcass characteristics were assessed in feedlot lambs. Thirty-two Santa Inês intact male lambs, with an average initial weight of 21.0 ± 2.3 kg, were assigned to a completely randomized block design with four treatments and eight replicates. Intake of DM, organic matter, ether extract, neutral detergent fibre and total digestible nutrients were not affected by the diets. However, the intake of crude protein (CP) was reduced by 0.2 g/day for each 1% increase in the replacement level of soybean meal with maize steep liquor. Replacement of soybean meal with maize steep liquor in the diets did not affect the apparent digestibility of nutrients with the exception of CP, which decreased by 14.1 g/kg DM for each 1% increase in the replacement level of soybean meal. Similar trends were observed for average daily gain, hot carcass weight, cold carcass weight, hot carcass yield and cold carcass yield. From these results, soybean meal could be replaced by up to 100% with maize steep liquor in finishing diets for feedlot lambs.

Keywords: Alternative feed, by-product, digestibility, intake, performance
[#] Corresponding author: silva_janainalima@yahoo.com.br

Introduction

Feeding contributes about 30% - 70% of the costs in an animal production system (Rodrigues & Rondina, 2013). Thus, to be competitive in the market, animal production should adopt dietary strategies that result in an economically viable system. Moreover, there is demand for over 500 million tons of grain to supply the agricultural sector (FAO, 2012) because of the increasing demand for animal products by the general population. Soybean meal is the main protein ingredient used around the world in animal diets (Jelali & Ben Salem, 2014). However, soybean meal is an expensive commodity that increases the cost of animal production. To solve these problems, studies have been conducted with alternative feeds to examine the effects of partial or total replacement of soybean meal in diets (Irshaid & Harb, 2003; Titi, 2003; Haddad, 2006; Silva *et al*., 2008; Santos *et al*., 2012).

The industrialization of processing maize grain results in a range of ingredients for the industrial sectors. For example, steeping is used during wet maize milling, and wet processing is normally used to remove impurities and separate the germ, gluten, starch and peel (USDA, 2010). In this process, the grains are transferred to macerator tanks, which receive water with SO_2 for cleansing and softening at up to 50% moisture. The maize steep liquor, with about 6% solids, is evaporated until it reaches 45% to 50% dry matter (DM) and 85% organic matter (OM) (Meneghetti & Domingues, 2008).

Maize steep liquor is available in various colours, ranging from dark yellow to brown (depending on the staying time of the product in the manufacturing process) with a pleasant smell and a high crude protein (CP) content, ranging from 400 to 500 g/kg on a DM basis (Mirza & Mushtaq, 2006; Nisa *et al*., 2006; Silva *et al*., 2008; Nasir *et al*., 2012; Santos *et al*., 2012). According to USDA (2010), maize steep liquor should not cause environmental contamination, since it contains 50% water and the soluble proteins, amino acids, carbohydrates, organic acids (e.g. lactic acid), vitamins and minerals would be readily metabolized and utilized by micro-organisms. In addition, SO_2 added to the fermented material is volatilized to the atmosphere. However, because of the generation of millions of tons of waste during wet maize milling, it is

URL: http://www.sasas.co.za
ISSN 0375-1589 (print), ISSN 2221-4062 (online)
Publisher: South African Society for Animal Science
http://dx.doi.org/10.4314/sajas.v45i5.9

necessary to find a way to manage this adequately (USDA, 2010). Therefore, maize steep liquor could be an alternative protein source in animal production.

Using crossbred (¾ Holstein x Gyr) cows with an average milk production of 15 kg/day, Silva *et al.* (2008) found no effects on daily milk production or the fat content of the milk when soybean meal was replaced with maize steep liquor. However, for high-producing cows (25 kg milk/day), Santos *et al.* (2012) reported a reduction in daily milk production without affecting the fat content. In buffalo calves, Nasir *et al.* (2012) reported that molasses plus maize steep liquor could successfully replace the concentrate portion in a ruminant diet, thereby reducing the cost of production. Mirza & Mushtaq (2006) verified that supplementation of maize steep liquor at 5% of the diet is useful for growth and feed : gain of Pak-Karakul post-weaning lambs. Nisa *et al.* (2012) replaced urea in the feed of intensively produced Lohi lambs with maize steep liquor and observed an increase in feed intake, which resulted in an improved growth rate and feed conversion ratio. Thus, it was hypothesized that maize steep liquor, which is high in CP, could replace soybean meal in supplementation in lamb production systems.

Therefore, owing to the low price of maize steep liquor in Brazil compared with soybean meal (around 50% cheaper) and lack of reported studies where this product was used to replace soybean meal, the purpose of this study was to evaluate the effects of replacing soybean meal with maize steep liquor. It was hypothesized that maize steep liquor could partially or totally replace soybean meal for finishing lambs without affecting intake and digestibility of nutrients, performance and carcass characteristics.

Materials and Methods

The experiment was conducted in the Laboratory of Feed Evaluation for Small Ruminants II in the Department of Animal Science of the Federal Rural University of Pernambuco, Recife, PE, Brazil. The basal diet (without maize steep liquor) was formulated to meet lamb requirements for maintenance and an average daily gain of 200 g stipulated by the National Research Council (NRC, 2007). The forage : concentrate ratio was 50 : 50 on a DM basis with Tifton hay as the forage, and ground maize, soybean meal and maize steep liquor as the ingredients of the concentrate. The diets consisted of four replacement levels of soybean meal with maize steep liquor (0%, 33%, 66% and 100% on a DM basis). The chemical compositions of the ingredients are shown in Table 1, and composition and analysis of the diets are shown in Table 2.

The management and care of animals were performed in accordance with the guidelines and recommendations of the Committee of Ethics on Animal Use at the Federal Rural University of Pernambuco (UFRPE), PE, Brazil. To determine nutrient intake and digestibility as well as productive performance, 32 Santa Inês intact male lambs with an average initial bodyweight (BW) of 21.0 ± 2.3 kg and four months of age were distributed throughout a randomized block design, with four treatments and eight replicates. The trial lasted 70 days and was divided into a 30-day adaptation period.

Animals were weighed, identified, vermifuged and vaccinated against *Clostridium* prior to the experiment and housed in individual pens (1.0 x 1.5 m) fitted with feeders and waterers. At the end of the adaptation period, the animals were weighed and, after 14 h fasting, were weighed again after the last experimental period. Feed was provided ad libitum as a total mixed ration (TMR) in two daily meals at 07:00 and 15:00, and adjusted daily according to the intake of the previous day, allowing orts of approximately 12% of the total DM provided. The orts were sampled, placed in labelled bags and stored in a freezer for later analysis. The ingredients of the diets were sampled weekly, totalling 10 samples per animal over the 70-day trial period.

After a 40-day experimental period, faecal DM output was estimated using LIPE® (modified and enriched hydroxyphenylpropane (purified lignin eucalyptus)) as an external marker to calculate total tract apparent digestibility of the feed nutrients (Lima *et al*., 2008). The marker was administered in the form of capsules (250 mg/animal) over seven days (two days for adaptation followed by five days for data collection) in the morning, at 07:00 (single dose). The faecal samples were collected rectally manually using disposable gloves, once a day from each animal, on the first to fifth days of the collection period at different hours (07:00, 0:00, 11:00, 13:00 and 15:00). All samples were frozen at −20 ºC and sent to the Animal Nutrition Lab at UFRPE, Recife (northeast Brazil). The samples were oven-dried at 65 ºC for 72 h and ground using a Wiley mill with a 1 mm screen. After drying, the samples were mixed to obtain one value for DM. The faecal samples were analysed according to the methodology of Saliba *et al.* (2003).

Dried ingredients, diets, orts and faecal samples were analysed for DM, OM, ash, CP, ether extract (EE), neutral detergent fibre (NDF) and acid detergent fibre (ADF), according to standard procedures (AOAC, 2005). Total carbohydrates (TC) were calculated according to Sniffen *et al.* (1992):

TC (g/kg) = 1000 - (CP + EE + ash).

Non-fibre carbohydrates (NFC) were calculated according to Hall *et al.* (1999):

NFC (g/kg) = 1000 - (NDF + CP + EE + ash)

The total digestible nutrient intake (TDNI) was calculated using the equation proposed by Sniffen *et al.* (1992):

$TDNI = {}_{D}CPI + {}_{D}TCI + (2.25 \times {}_{D}EEI)$

in which: ${}_{D}CPI$ = digestible crude protein intake, ${}_{D}TCI$ = digestible total carbohydrate intake and ${}_{D}EEI$ = digestible ether extract intake.

At 70 days, the animals were subjected to solid fasting for 16 hours, weighed to obtain the final weight, and stunned by concussion through non penetrative percussion, suspended by the hind legs with ropes, and bled by cutting the carotid arteries and jugular veins. Blood was collected and weighed, and the minimum bleed time was three minutes (Brasil, 2000).

Table 1 Chemical composition of the ingredients (g/kg on DM basis)

Nutrients	Ingredients			
	Tifton hay	Ground maize	Soybean meal	Maize steep liquor
Dry matter, g/kg	884.7	882.6	897.4	410.0
Organic matter	928.4	989.6	937.1	854.1
Minerals	71.6	10.4	62.9	145.9
Crude protein	62.7	91.4	516.9	500.0
Ether extract	36.0	43.4	23.5	11.5
Neutral detergent fibre	678.3	191.4	209.1	18.0
Acid detergent fibre	336.2	28.1	73.2	9.0
Total carbohydrates	801.0	884.0	397.0	343.0
Non-fibre carbohydrates	122.7	692.1	187.6	325.0

Table 2 Composition and chemical analysis of the experimental diets (DM basis)

	Maize steep liquor (%)			
	0	33	66	100
Ingredients (g/kg)				
Tifton hay	500.0	500.0	500.0	500.0
Ground maize	335.0	335.0	335.0	335.0
Soybean meal	150.0	100.0	50.0	0.0
Maize steep liquor	0.0	50.0	100.0	150.0
Minerals	15.0	15.0	15.0	15.0
Chemical composition (g/kg DM)[1]				
Dry matter, g/kg	922.2	897.8	873.4	849.1
Crude protein	152.7	151.9	151.0	150.2
Ether extract	36.1	35.5	34.9	34.3
Neutral detergent fibre	439.3	429.6	419.8	410.0
Acid detergent fibre	188.5	184.8	181.2	177.5
Total carbohydrates	756.2	754.0	750.8	748.1
Non-fibre carbohydrates	294.0	268.8	243.6	218.4

[1] Chemical composition of diets obtained from laboratory analysis of ingredients.

While still suspended, the animals were scraped manually with ordinary knives. The head was separated by sectioning the cervical vertebrae at the atlanto-occipital joint. The feet were obtained by sectioning the forelimbs at the carpal-metacarpal joints and the hind limbs at the metatarsal-tarsal joints. The gastrointestinal tract content was quantified by the weight difference between full and empty guts. The empty bodyweight (EBW) matched final weight at slaughter BWS (without gastrointestinal content).

The hot carcass was obtained from the body of the slaughtered, bled, skinned and gutted animal, free of the limbs, kidneys, and perirenal fat (Brasil, 2000). Once the hot carcass weight (HCW) had been obtained, the carcass were taken to the cold chamber, which had a mean temperature of 4 ºC, where it remained for 24 h suspended on hooks by the gastrocnemius muscle tendon. The carcass weight after 24 h of cooling corresponded to the cold carcass weight (CCW). Next, the kidneys and perirenal fat were removed. They were subtracted from the HCW and CCW to calculate the yields of the hot (HCY) and cold carcass (CCY) using these formulae:

HCY (%) = (HCW/BWS) x 100, CCY (%) = (CCW/BWS) x 100

Analysis of variance (ANOVA) and regression were performed using the software Statistical and Genetics Analysis System (SAEG®), adopting a 0.05 probability of a type I error (UFV, 2007) to determine the effects of replacing soybean meal with maize steep liquor on intake and digestibility of nutrients, performance and carcass characteristics.

Results and Discussion

The intakes of DM, OM, EE, NDF and TDN showed no difference (P >0.05) because of replacing soybean meal with maize steep liquor, except for CP (Table 3). This is explained by the similar levels of these nutrients in the various diets, with the exception of CP. Unlike the present study, Nisa *et al.* (2012) observed increased nutrient intake and better utilization of the diet, but the levels of maize steep liquor tested were up to 14% of the diet. The authors suggested that the increased nutrient intake resulted from the improved palatability of the diet, without a physiological explanation. However, Mirza & Mushtaq (2006) reported a reduced feed intake in lambs.

Table 3 Mean daily intake of dry matter and nutrients (kg/day) of feedlot lambs (n = 8 animals per treatment) fed diets containing different replacement levels of soybean meal with maize steep liquor

Nutrients	Maize steep liquor (%)				Regression	SEM	r^2
	0	33	66	100			
Dry matter	1.14	1.1	1.1	1.1	$\hat{Y}$ = 1.103	0.056	-
Dry matter (%BW)	4.1	4.1	4.0	3.8	$\hat{Y}$ = 4.0	0.098	-
Organic matter	1.1	1.1	1.1	1.0	$\hat{Y}$ = 1.055	0.047	-
Crude protein	0.17	0.17	0.16	0.15	$\hat{Y}$ = 0.172 – 0.0002X*	0.008	0.98
Ether extract	0.03	0.03	0.03	0.03	$\hat{Y}$ = 0.029	0.00034	-
Neutral detergent fibre	0.48	0.47	0.46	0.43	$\hat{Y}$ = 0.458	0.026	-
Total digestible nutrients	0.76	0.74	0.75	0.72	$\hat{Y}$ = 0.740	0.043	-

*P <0.05. SEM: standard error of mean.
BW: body weight.

Crude protein intake was reduced (P <0.05) with 1% increase in the levels of replacement of soybean meal with maize steep liquor. Santos *et al.* (2012) evaluated alternative sources of protein for lactating cows and reported that when maize steep liquor was used, there was lower intake of CP compared with when soybean meal was used, owing to the lower DM intake. In this case, the authors suggested that feed refusal was owing to palatability, because maize steep liquor has a bitter taste (pH = 3.7) (Mirza & Mushtaq, 2006), and probably this was the cause in the present study.

The apparent digestibility of DM, OM, EE, and NDF showed no difference (P >0.05) because of replacing soybean meal with maize steep liquor (Table 4). The apparent digestibility of CP showed a linear decrease (P <0.05), of 14.1 g/kg DM for each 1% increase in replacement levels of soybean meal with maize steep liquor. One hypothesis is that this is because of the presence of acid detergent insoluble nitrogen (ADIN) in the maize steep liquor. Nisa *et al.* (2006) observed that NDIN and ADIN levels in the diets based

on urea-treated wheat bran (UTWS) increased linearly with increasing levels of maize steep liquor when ensiled with UTWS. In addition, there is a relationship between ADIN and nitrogen (N) indigestibility, that is, essentially a one-to-one reduction in N digestibility as ADIN increased (Nakamura *et al*., 1994). Another hypothesis is the increase in the rate of passage of the feed in liquid form. According to Van Soest (1994), the digestibility of nutrients can be influenced by feed intake, feed retention time in the rumen, quality and quantity of the fibre composition of the feed, feed preparation, protein : energy ratio, rate of degradability, and factors inherent to the animal.

Table 4 Mean apparent digestibility (g/kg) of feedlot lambs (n = 8 animals per treatment) fed diets containing different replacement levels of soybean meal with maize steep liquor

Nutrients	Maize steep liquor (%)				Regression	SEM	r^2
	0	33	66	100			
Dry matter	784.0	780.0	770.0	758.0	$\hat{Y}$ = 773.0	13.56	-
Organic matter	796.0	793.0	792.0	783.0	$\hat{Y}$ = 791.0	12.76	-
Crude protein	828.0	833.0	800.0	792.0	$\hat{Y}$ = 848.5 – 14.1X*	14.56	0.80
Ether extract	674.0	696.0	639.0	622.0	$\hat{Y}$ = 658.0	17.89	-
Neutral detergent fibre	752.0	719.0	713.0	706.0	$\hat{Y}$ = 722.0	19.43	-

**P* <0.05. SEM: standard error of mean.

The replacement of soybean meal with maize steep liquor had no effect (*P* >0.05) on BWS, total weight gain (TG) and average daily gain (ADG) in the feedlot lambs (Table 5). Average performance values of 34.2 kg, 13.27 kg and 0.183 kg/day were found for BWS, TG and ADG, respectively. This result is due to the lack of effect on DM and TDN intakes, indicating that the animals met their requirements for maintenance and gain. Although there was a reduction in CP intake, the requirements of CP (120 g/day) and TDN (560 g/day) were attended to, according to the National Research Council (NRC, 2007), without compromising the average daily gains that were close to 200 g/day.

Table 5 Mean performance and carcass characteristics of feedlot lambs (n = 8 animals per treatment) fed diets containing different replacement levels of soybean meal with maize steep liquor

Performance	Maize steep liquor (%)				Regression	SEM
	0	33	66	100		
Initial body weight (kg)	20.44	21.01	21.01	21.02	$\hat{Y}$ = 20.87	0.807
Final body weight (kg)	34.87	34.07	33.75	33.70	$\hat{Y}$ = 34.10	0.978
Total gain (kg)	14.45	13.15	12.76	12.71	$\hat{Y}$ = 13.27	0.454
Average daily gain (kg/day)	0.200	0.182	0.176	0.175	$\hat{Y}$ = 0.183	0.032
Carcass characteristics						
Empty body weight (kg)	29.34	28.73	28.09	27.80	$\hat{Y}$ = 28.49	0.546
Hot carcass weight (kg)	16.39	16.21	15.99	15.63	$\hat{Y}$ = 16.05	0.654
Cold carcass weight (kg)	15.94	15.72	15.44	15.13	$\hat{Y}$ = 15.56	0.546
Hot carcass yield (%)	46.84	47.47	47.39	46.30	$\hat{Y}$ = 47.00	0.671
Cold carcass yield (%)	45.57	46.00	45.77	44.83	$\hat{Y}$ = 45.54	0.745

SEM: standard error of mean.

As in the present study, positive results from the use of maize steep water were found in the literature. Mirza & Mushtaq (2006) reported that maize steep liquor at higher supplemental rates, that is, 10% or 15% of the basal diet, had no significant effect on the body weight gain of Pak-Karakul lambs. Likewise, Nisa *et al*. (2012) reported increased weight gain in lambs fed diets containing high levels of maize steep liquor replacing urea (80% replacement), which was because of the increased nutrient intake and better utilization of the diet.

A similar trend was observed for carcass characteristics (Table 5), which showed no difference (P >0.05) because of replacing soybean meal with maize steep liquor. Average carcass characteristics values of 16.05 and 15.56 kg were found for HCW and CCW, respectively. As for carcass yield, average values of 47.0% and 45.5% were found for hot carcass yield (HCY) and cold carcass yield (CCY), respectively. The hot and cold carcass yield were close to the average values (HCW ≥ 14.4 kg and CCW ≥ 13.8 kg; HCY = 46% and CCY = 44.5%), recommended by Silva Sobrinho (2001).

The results from the evaluation of carcass characteristics indicated that a similar performance among lambs, based on body weight at slaughter, resulted in similar weights and carcass yields. Therefore, it can be inferred that in all carcasses, regardless of the level of replacement, there was similar capacity for development and tissue growth, which agrees with the findings of Faria *et al.* (2011). The similarity observed in these variables is a result of the standardization of the carcasses and the relationship between weight at time of slaughter and carcass parameters.

Conclusion

Soybean meal could be replaced by up to 100% with maize steep liquor in finishing diets for feedlot lambs without affecting daily gain and carcass characteristics. In addition, in Brazil maize steep liquor is more economically viable than soybean meal, reflecting in the profitability of the production system.

Conflict of Interest

The authors wish to confirm that no known conflicts of interest are associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

References

AOAC, 2005. Official Method of Analysis, 18th ed. Association of Official Analytical Chemists, Washington DC, USA.

Brasil, Ministério da Agricultura, Pecuária e do Abastecimento (MAPA). Secretaria da Defesa Agropecuária (SDA). Departamento de Inspeção de Produtos de Origem Animal (DIPOA). Divisão de Normas Técnicas. Instrução Normativa n. 3, de 17 de Janeiro de 2000. Lex: Diário Oficial da União de 24 de janeiro de 2000, Seção 1, 14-16. (in Portuguese)

FAO, 2012. Balanced feeding for improving livestock productivity – Increase in milk production and nutrient use efficiency and decrease in methane emission. Food and Agriculture Organization of the United Nations, Animal Production and Health Paper No. 173. Rome, Italy.

Faria, P.B., Silva, J.N., Rodrigues, A.Q., Teixeira, P.D., Melo, L.Q., Costa, S.F., Rocha, M.F.M. & Pereira, A.A., 2011. Processamento da casca de mandioca na alimentação de ovinos: desempenho, características de carcaça, morfologia ruminal e eficiência econômica. Rev. Bras. Zootecn. 40, 2929-2937. (in Portuguese)

Haddad, S.G., 2006. Bitter vetch grains as a substitute for soyabean meal for growing lambs. Livest. Sci. 99, 221-225.

Hall, M.B., Hoover, W.H., Jennings, J.P. & Webster, T.K.M., 1999. A method for partitioning neutral detergent soluble carbohydrates. J. Sci. Food Agr. 79, 2079-2086.

Irshaid, R.H. & Harb, M.Y., 2003. Replacing soyabean meal with sunflower seed meal in the ration of Awassi ewes and lambs. Small Rumin. Res. 50, 109-116.

Jelali, R. & Ben Salem, H., 2014. Daily and alternate day supplementation of *Moringa oleifera* leaf meal or soyabean meal to lambs receiving oat hay. Livest. Sci. 168, 84-88.

Lima, J.B.M.P., Graça, D.S., Borges, A.L.C.C., Saliba, E.O.S. & Simão, S.M.B., 2008. Uso do óxido crômico e do LIPE® na estimativa do consumo de matéria seca por bezerros de corte. Arq. Bras. Med. Vet. Zootec. 60, 1197-1204. (in Portuguese)

Meneghetti, C.C. & Domingues, J.L., 2008. Características nutricionais e uso de subprodutos da agroindústria na alimentação de bovinos. Nutritime 5, 512-536.

Mirza, M.A. & Mushtaq, T., 2006. Effect of supplementing different levels of maize steep liquor on the post-weaning growth performance of pak-karakul lambs. Pakistan Vet. J. 26, 135-137.

Nakamura, T., Klopfenstein, T.J. & Britton, R.A., 1994. Evaluation of acid detergent insoluble nitrogen as an indicator of protein quality in nonforage proteins. J. Anim. Sci. 72, 1043-1048.

Nasir, T., Sarwar, M., Ahmad, F., Tipu, M.A. & Hussain, I., 2012. Influence of substitution of concentrate with molasses and maize steep liquor on nutrient intake, weight gain and feed conversion efficiency of buffalo calves. J. Anim. Plant Sci. 22, 296-300.

Nisa, M., Khan, M.A., Sarwar, M., Lee, W.S., Lee, H.J., Ki, K.S., Ahn, B.S. & Kim, H.S., 2006. Influence of maize steep liquor on feeding value of urea treated wheat straw in buffaloes fed at restricted diets. Asian Australas. J. Anim. Sci. 19, 1610-1616.

Nisa, M., Shahzad, M.A., Phillips, C.J.C. & Sarwar, M., 2012. Responses to graded replacement of urea by maize steep liquor in diets of intensively fed lambs for meat production. Trop. Anim. Health Prod. 44, 947-952.

NRC, 2007. Nutrient Requirements of Small Ruminants. National Research Council, National Academy Council, Washington D.C., USA. p. 362.

Rodrigues, F.V. & Rondina, D., 2013. Alternativas de uso de subprodutos da cadeia do biodiesel na alimentação de ruminantes: Glicerina bruta. Acta Vet. Bras. 7, 91-99. (in Portuguese)

Saliba, E.O.S., Rodriguez, N.M. & Piló-Veloso, D., 2003. Utilization of purified lignin extracted from *Eucalyptus grandis* (PELI), used as an external marker in digestibility trials in various animal species. In: Proceedings of the World Conference on Animal Production - 9,. Porto Alegre, Brazil.

Santos, V.L.F., Ferreira, M.A., Guim, A., Silva, F.M., Urbano, S.A. & Silva, E.C., 2012. Protein sources for crossbred dairy cows in the semiarid. Rev. Bras. Zootecn. 41, 2272-2278.

Silva Sobrinho, A.G., 2001. Aspectos quantitativos e qualitativos da produção de carne ovina. In: FEALQ (Ed.). A produção animal na visão dos brasileiros. 1.ed. Piracicaba: Fundação de Estudos Agrários Luiz de Queiroz. pp.425-446. (in Portuguese)

Silva, M.J.M.S., Ferreira, M.A., Melo, A.A.S., Monteiro, M.C.C., Ferreira, B.F. & Ribeiro, V.L., 2008. Níveis de inclusão do resíduo do milho (mazoferm), em substituição ao farelo de soja para vacas em lactação. Acta Sci. Anim. Sci. 30, 51-57. (in Portuguese)

Sniffen, C.J.O., O'Connor, J.D., Van Soest, P.J., Fox, D.G. & Russell, J.B., 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. J. Anim. Sci. 70, 3562-3577.

Titi, H.H., 2003. Replacing soybean meal with sunflower meal with or without fibrolytic emzymes in fattening diets of goat kids. Small Rumin. Res. 48, 45-50.

Universidade Federal de Viçosa - UFV, 2007. Sistema de análises estatísticas e genéticas - SAEG. Versão 8.0. Viçosa, MG. 142 p.

USDA, 2010. Technical Evaluation Report. Compiled by the Technical Services Branch for the USDA National Organic Program. February 1. pp. 1-18.

Van Soest, P.J., 1994. Nutritional Ecology of the Ruminant. 2nd ed. London: Constock Publishing Associates, 476 p.