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Use of macaúba cake replacing corn on carcass characteristics and body measurements of Santa Inês lambs[1]

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ABSTRACT - This experiment evaluated the effect of adding macaúba (*Acrocomia aculeata*) cake replacing corn on body measurements and carcass characteristics of Santa Inês lambs. Twenty four 5-month-old uncastrated male lambs were tested using a randomized blocks design. Lambs were distributed into four experimental groups, receiving diets with 0, 100, 200 and 300 g/kg of macaúba cake. After 60 days in feedlot, measurements of body length, thoracic perimeter, height at the anterior and rump height were taken. The lambs were slaughtered, skinned and eviscerated. Carcass were weighed hot and chilled at 2 ºC during 24 h. Cooling losses, hot carcass weight, cold carcass weight, hot carcass yield, cold carcass yield, half carcass weight, fat thickness, final weight, slaughter weight, empty body weight, thorax depth, croup width, perimeter of the croup, carcass length, internal carcass length, hindlimb length, hindlimb width and hindlimb conformation score were evaluated. Only hindlimb width was inversely correlated to adding macaúba cake in the diet. Macaúba cake can be included in diets for lamb in feedlot up to 300 g/kg without affecting body measurements *in vivo* or carcass characteristics.

Key Words: agro-industrial residue, byproduct, feeding, feedlot, small ruminants

Introduction

Sheep meat consumption is low in Brazil, mainly because of poor meat quality, irregular supply and high price. Brazilian sheep meat is in general obtained from old-aged animals, which have undesirable carcass characteristics and low edible matter content (Furusho Garcia et al., 2000). This problem, however, can be controlled using suitable husbandry practices such as feedlot management.

Feedlot management is an operation of entrepreneurial nature that attempts to increase production rates and improve product quality. However, the implementation of feedlot management increases production costs. Many byproducts have been studied by researchers with the aim to replace expensive conventional feeds (Medeiros et al., 2009).

In this scenario, the macaúba cake is a byproduct of macaúba oil extraction that can be used in animal feeding. Macaúba (*Acrocomia aculeata* (Jacq.) Lodd. ex Martius) is a palm widely found in the semi-arid areas of Brazil, which produces fruits with high oil contents (Hiane et al., 2005).

Chemical analyses of macaúba cake indicate that it can theoretically be used for ruminant feeding (Rufino et al., 2011). However, the high content of ether extract and neutral detergent fiber are variables that can limit the use of this byproduct for lamb feeding and change carcass characteristics.

This experiment was carried out to evaluate the effect of adding macaúba cake at replacing corn on body measurements and carcass characteristics of lambs.

Material and Methods

The research was carried out from November 15, 2008, to January 28, 2009, in the Institute of Agricultural Sciences of the Universidade Federal de Minas Gerais, in Montes Claros, MG, Brazil (16º51'38" S latitude; 44º55'00" W longitude). This area is typically semi-arid, with a dry climate and high average temperatures that range from 25 to 35 ºC. Twenty-four 5-month-old uncastrated male Santa Ines lambs with average live weight of 23.9±2.7 kg were used. Lambs were individually identified and prior to the experiment, underwent sanitary management with anthelmintics, consisting of ivermectin administration and vaccination against clostridiosis. The lambs were held in 1.00 × 1.20 m bare ground individual pens provided with feeding and drinking troughs and thick sawdust bedding.

The lambs were blocked by initial weight and then randomly assigned to 1 of 4 treatments: 0, 100, 200 or 300 g

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of macaúba cake/kg DM. Feeding was offered twice a day (7 a.m and 5 p.m) and water was supplied *ad libitum*. Forage and concentrate content was weighed daily to match feed intake requirements and allow 20% of orts. Sorghum silage was used as forage, and the concentrate was composed of ground corn, soybean meal, cottonseed, vitamin mineral premix, dicalcium phosphate and common salt. Diets (Table 1) were formulated to meet the requirements of sheep of 25 kg of live weight (LW) and daily gain of 200 g/day (NRC, 1985).

Macaúba cake was obtained from macaúba fruits squeezed for oil extraction by the Cooperativa de Pequenos Produtores Rurais de Riacho D'antas e Adjacências, in Montes Claros, Minas Gerais.

At the end of the experimental period, the animals were weighed, thus obtaining the final weight and subjected to solid fasting of 12 hours. After this period, the animals were weighed again to obtain the slaughter weight and measurement of body length, thoracic perimeter, height at the anterior and rump height. For measurements with a metric tape graduated in centimeters, lambs were positioned on a flat surface, in the horizontal position, as proposed by Osório et al. (1998) and Santana et al. (2001). Body length is defined as the distance between the cervicothoracic junction and the base of the tail. Rump height is the distance from the sacral tuberosity in the croup to the distal hindlimb extremity, and height in the anterior, the distance of sacral tuberosity in the croup to the distal forelimb extremity. Thoracic perimeter represented body circumference measured at the shoulder level (Yáñez et al., 2004; Cezar & Souza, 2007).

Table 1 - Composition of the ingredients in the diets (g/kg DM) and experimental diets according to macaúba cake levels

Ingredient	Composition (g/kg DM)			
Sorghum silage	300.0	300.0	300.0	300.0
Corn	486.5	384.0	281.4	178.9
Cottonseed	50.0	50.0	50.0	50.0
Soybean meal	149.8	153.0	156.1	159.3
Macaúba cake	0.0	100.0	200.0	300.0
Dicalcium phosphate	3.3	3.3	3.4	3.4
Limestone (calcium carbonate)	7.4	6.7	6.1	5.4
Salt	2.8	2.8	2.8	2.8
Vitamin mineral premix	0.2	0.2	0.2	0.2
Composition (g/kg DM)	Macaúba levels (g/kg DM)			
	0	100	200	300
DM (g/kg)	729.2	739.4	743.0	748.0
CP (g/kg)	150.1	158.8	158.1	157.4
EE (g/kg)	39.0	49.5	62.0	67.9
NDF (g/kg)	320.9	363.5	408.8	431.7
ADF (g/kg)	83.7	134.8	201.1	233.6
TDN (g/kg)	742.4	732.8	723.1	713.5

DM - dry matter; CP - crude protein; TDN - total digestible nutrients; EE - ether extract; NDF - neutral detergent fiber; ADF - acid detergent fiber.
Total digestible nutrients (TDN = 40.2625 + 0.1969 CP + 0.4028 NFC + 1.903 EE – 0.1379 ADF, Weiss, 1998).

At slaughter, the animals were stunned by concussion in the atlanto-occipital region, followed by bleeding through the section of the carotid artery and jugular vein. This was followed by skinning and evisceration. The contents of the gallbladder, bladder and digestive components (rumen/reticulus, omasum, abomasum, small and large intestines) were weighed. The gastrointestinal tract was weighed full and empty to determine the empty body weight (EBW), which was used to determine the biological or true yield (TY,% = (HCW /EBW) × 100).

To determine hot carcass weight (HCW), the head (section in the atlantooccipital joint) and the paws (section in the carpal and tarsal-metatarsal joints) were separated. Carcasses were wrapped in plastic bags, identified and transported to a cold chamber, where they were stored for 24 h at 2 °C. Carcasses were then weighed again to determine cold carcass weight (CCW). The calculation of cooling losses (CL) followed the equation CL (%) = (HCW-CCW) × 100/HCW. Hot carcass yield represented the ratio between slaughter weight and hot carcass weight, while cold carcass yield was the ratio between slaughter weight and cold carcass weight (Pérez & Carvalho, 2002). Half-carcass weight was measured after carcasses were sectioned longitudinally.

Fat thickness was evaluated in a section removed from the external portion of the *longissimus dorsi* muscle, between the 12th and 13th ribs. Fat thickness was measured using a digital caliper.

For morphometrical carcass evaluation, the measures made were carcass length, from the upper edge of the pubis to the upper edge of the first rib; croup width, maximal distance between femoral trochanters; thorax depth, maximal distance from the dorsal axis to the sternum at the level between the the 3rd and 4th ribs; perimeter of the croup, around femoral trochanters; internal carcass length, from the ischiopubic symphysis to the first rib; hindlimb length, from the upper edge of the pubis to the median point of the tarsal bones, measured in the internal portion of the limb; and hindlimb width, measured in the medium-lateral portion of the thigh. Measures were taken with a metal compass and meter tape graduated in centimeters according to Fisher & Boer (1994).

Hindlimb conformation score was determined by the ratio between croup width and hindlimb length, as proposed by Siqueira et al. (2001).

The experimental design used was randomized blocks with four treatments and six replicates, and the blocks were

formed according to the initial weight of animals. After analysis of variance, the sum of squares of the treatments was orthogonally decomposed into linear, quadratic and cubic effects of macaúba cake levels in the diet. Regression models were then adjusted following the significance of effects pointed out by analysis of variance. Statistical analysis was performed by using the software SAEG (Sistema para Análises Estatísticas,version 8.0) adopting $\alpha = 0.05$.

Results and Discussion

Macaúba cake inclusion in lamb diets (Table 2) did not affect body measures *in vivo*. Despite its high fiber content, adding 300 g/kg DM of macaúba cake replacing corn did not significantly decrease nutrient content.

Lambs from all the treatments showed normal body development, with average slaughter weight of 35.7 kg and weight gain and dry matter intake comparable with those reported in other studies. For instance, Rufino et al. (2009) reported an average of 1124.9 g/day of dry matter intake and 199 g of daily weight gain in lambs. Similarly to the present study, Marques et al. (2008) found that dietary inclusion of silk flower (*Calotropis procera* SW) did not affect the biometry of Santa Inês lambs slaughtered at around 30 kg (body length = 55.39 cm, height of the anterior = 61.91 cm and rump height = 65.76 cm).

According to Santos et al. (2009), the addition of rapeseed grains, meal and cake to the dietary protein concentrate did not affect nutrient digestibility or biometric measurements of Santa Inês male lambs. The biometric measures obtained in the present study were higher than those reported by Santos et al. (2009), but this was expected, since the animals studied were two months older.

The dietary inclusion of macaúba cake did not compromise carcass proportions in terms of hot carcass weight, cold carcass weight, cooling losses, hot carcass yield, cold carcass yield, half-carcass weight or fat thickness (Table 3).

Considering that lamb performance, feed intake and body measurements in live lambs were also similar between treatments, equal carcass measurements is an expected result. Oliveira et al. (2002) studied Santa Inês and Bergamácia lambs finished in feedlot and fed diets containing residues from pig farming, similarly to the present study, and found no treatment effect on hot carcass weight (23.3 kg), hot carcass yield (53.3%), cold carcass weight (23.0kg), cold carcass yield (52.6%) or cooling losses (1.20%).

The hot and cold carcass yield values obtained were similar to those reported by Santos et al. (2009) for Santa Ines lambs finished with canola grain and byproducts (hot carcass yield = 46.2% and cold carcass yield = 45.7%).

Table 2 - Means of body measurements of lambs according to addition of macaúba cake level in the diet

Variable (cm)	Macaúba levels (g/kg DM)					P		
	0	100	200	300	CV (%)	L	Q	C
BL	69.8	60.1	70.4	70.3	18.0	0.886	0.528	0.572
T P	77.5	78.6	77.8	77.7	3.0	1.000	0.660	0.668
RH	66.6	67.3	66.7	68.4	2.4	0.302	0.635	0.403
HA	66.3	68.0	65.7	68.0	2.9	0.544	0.791	0.068

BL - body length; TP - thoracic perimeter; RH - rump height; HA - height at the anterior; L, Q, C - linear quadratic and cubic effects of macaúba cake levels in the diet, respectively; DM - dry matter; CV - coefficient of variation.

Table 3 - Means of carcass characteristics of lambs according adding of macaúba cake level in the diet

Variable	Macaúba levels (g/kg DM)					P		
	0	100	200	300	CV (%)	L	Q	C
HCW (kg)	17.07	17.66	16.97	16.47	7.0	0.524	0.533	0.706
CCW (kg)	16.59	17.16	16.42	16.03	7.2	0.532	0.578	0.669
CL (%)	2.85	2.84	3.25	2.70	21.5	0.957	0.319	0.248
HCY (%)	47.74	49.03	47.62	46.76	3.1	0.145	0.108	0.268
CCY (%)	46.37	47.64	46.07	45.50	3.4	0.167	0.174	0.205
HfCW (kg)	7.38	7.48	7.18	6.98	7.3	0.390	0.706	0.764
FT (mm)	1.62	1.40	1.89	1.83	4.5	0.428	0.809	0.384
FW (kg)	36.8	37.1	37.1	36.1	12.1	0.807	0.753	0.944
SW (kg)	35.8	36.1	35.8	35.2	12.2	0.814	0.809	0.975
EBW (kg)	31.2	31.9	30.9	30.1	12.8	0.576	0.657	0.815

HCW - hot carcass weight; CCW - cold carcass weight; CL - cooling losses; HCY - hot carcass yield; CCY - cold carcass yield; HfCW - half carcass weight; FT - fat thickness; FW - final weight; SW - slaughter weight; EBW - empty body weight; L, Q, C - linear, quadratic and cubic effects of macaúba cake levels in the diet, respectively; DM - dry matter; CV - coefficient of variation.

According to Sañudo & Sierra (1986), the dressing-out percentage (commercial carcass yield) ranges from 40 to 60%, depending on the breed, crossbreeding and husbandry system. The mean dressing-out of 46.39% obtained in the present study is within this range, showing that dietary macaúba cake can produce satisfactory carcass yields.

Cooling losses were similar in lambs from the different treatments, due to their similarity in fat thickness. This fat layer has a protective effect on the carcass by forming a barrier against water loss (Silva Sobrinho et al., 2005). The average cooling losses of 2.91% obtained in the present study is close to that of 2.78% obtained by Cunha et al. (2008) for Dorper × Santa Ines crossbred lambs slaughtered at 29.13 kg body weight. This value is below the maximum acceptable levels of cooling losses, which range from 3.0 to 4.0%. Thus, the experimental diets used provided good back fat formation, and this result is associated to the adequate slaughtering weight of the studied lambs. Moreover, the low cooling losses obtained indicates that the carcasses were kept in good storage conditions.

According to Monteiro et al. (1999) an adequate subcutaneous cover is necessary to promote protection against excessive water losses and to avoid muscle fiber shrinkage and meat darkening during chilling. Cartacho et al. (2009) found 1.25 mm fat thickness and body condition scores of 4 to 5 in carcasses of feedlot Santa Ines lambs fed 300 g maniçoba hay/kg DM (*Manihot pseudoglaziovii*) and 700 g concentrate/kg DM. These lambs were younger and lighter than the lambs studied in the present study, which had fat thickness of 1.68 mm. Furthermore, macaúba cake may have contributed to fat deposition in the carcass, which prevented excessive water loss during chilling. Similarly to the present study, Urano et al. (2006) found 1.8 mm fat thickness in Santa Ines lambs aged 170 days and weighing 37.7 kg.

The results presented show that macaúba cake can provide the nutrient content required for good lamb body tissue development. The lambs tested had satisfactory carcass weight and edible portion yield as well as fat deposition. Despite its high fiber content, 300 g macaúba cake/kg DM did not significantly decrease nutrient content, possibly because it did not limit dry matter intake, as described by Rufino et al. (2009). Moreover, although macaúba cake increased the ether extract in the diet to 67.9 g/kg DM, it did not increase back fat cover in carcass or carcass yield. This is an interesting result, since these parameters are probably changed by diets with such ether extract levels.

Carcass measurements were not changed by dietary addition of macaúba cake level, except for hindlimb width (Table 4).

A negative correlation was obtained in the regression analysis between dietary level of macaúba cake addition and hindlimb width. This result may be associated to a compensatory effect of total carcass development, given that lambs fed with macaúba cake had a slight but non-significant increase in carcass length, which was not associated to changes in carcass weight, yield or hindlimb conformation. Therefore, the decrease in hindlimb width may be evaluated along with the other anatomical structures.

Most carcass measurements were not significant among treatments (P>0.05), but the results are in accordance with other studies. For instance, Xenofonte et al. (2009) reported that uncastrated male lambs of undetermined breed, 4.6±0.8 months of age, subjected to diets with four levels of babaçu cake had carcass length of around 54.0 cm. Louvandini et al. (2007) found similar results, with carcass length of 63 cm and hot carcass dressing of 45.7% in Santa Inês lambs fed diets with sunflower meal instead of soybean meal.

Furusho Garcia et al. (2000) reported that Texel × Bergamácia crossbred, Texel × Santa Ines crossbred and pure Santa Ines lambs fed diets with coffee byproducts had short hindlimb length of 22.5 cm and low thorax depth

Table 4 - Means of morphometric measurements of the carcass of lambs according addition of macaúba cake level in the diet

Variable (cm)	Macaúba levels (g/kg DM)					P		
	0	100	200	300	CV (%)	L	Q	C
TD	27.2	27.1	27.4	27.2	4.2	0.864	0.918	0.664
CW	22.7	22.8	22.7	22.4	3.3	0.668	0.610	1.000
CP	63.6	63.6	62.8	63.0	2.3	0.561	0.901	0.665
CL	47.2	50.4	50.3	50.4	4.4	0.137	0.275	0.581
ICL	61.1	62.2	62.7	61.4	3.1	0.767	0.321	0.834
LW[1]	15.2	15.1	14.4	14.2	4.4	0.019	0.904	0.596
LL	41.5	42.5	42.1	41.7	2.9	0.918	0.185	0.602
LCS	0.54	0.53	0.53	0.53	0.9	0.597	0.657	0.739

TD - thorax depth; CW - croup width; CP - perimeter of the croup; CL - carcass length; ICL - internal carcass length; LL - hindlimb length; LW - hindlimb width; LCS - hindlimb conformation score; L, Q, C - linear, quadratic and cubic effects of macaúba cake levels in the diet, respectively; DM - dry matter; CV - coefficient of variation.
[1]$Y = 15.28-0.0038x \quad R^2 = 0.915$.

of around 28.7 cm. These authors attribute this response to the lower nutrient availability promoted by the coffee hull, which is a lignified ingredient that affects bone growth. This response is more pronounced in the most susceptible body parts, such as the thorax and the legs. Similarly, the present study detected a treatment effect only in the hindlimbs.

Conclusions

Macaúba cake can be included in diets for lambs in feedlot replacing corn up to 300 g/kg without affecting physical characteristics of the carcasses. However, the use of this byproduct depends on its cost in comparison with other ingredients

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