Substitution of corn for mesquite pod meal in diets for lambs

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Abstract

This study aimed to evaluate intake, digestibility, ingestive behaviour, and body weight variation in lambs fed mesquite pod meal (0, 30, 60 and 90%) in substitution of ground corn grains (as-fed basis) in pelleted diets. Twelve Santa Inês×Dorper lambs with average body weight of 25.0±1.8 kg were distributed through three 4×4 Latin Squares consisting of four periods and four treatments. Diets consisted of 30% alfalfa hay and 70% concentrate. The experimental period was 60 days, divided into 15-day periods. The intakes of dry matter (DM), total carbohydrates (TC) and total digestible nutrients (TDN) were not influenced (P>0.05) by the different levels of mesquite pod meal added in substitution of corn. The digestibility coefficients of DM, organic matter (OM), ether extracts (EE), neutral detergent fibre (NDFap), TC and the TDN decreased linearly (P<0.05) as the level of mesquite pod meal in the diet was increased. Feed efficiency [g DM and neutral detergent fibre (NDF)/hour] was not influenced (P>0.05) by the mesquite pod meal levels; contrastingly, this feedstuff caused a reduction of 12.13 and 1.9 g in rumination efficiency (g DM and NDF/hour, respectively) for every percentage unit added. The average weight gain showed quadratic behaviour (P<0.05) as a result of the substitution level, and maximum weight gain was estimated at 275.9 g/day at the substitution level of 47.5%.

Introduction

The Brazilian sheep herd amounts to approximately 16.1 million units. Of this total, 9.56 million (56.9%) of the national herd are found in the Northeast region, which makes it the largest producing region in the country (ANUALPEC, 2010). In spite of this expressive number, the animal productivity rates in that region are still considered low. A strategy to improve the performance of north-eastern small-ruminant herds, characterized by low productivity rates, is an adequate nutrition management, especially at times of feed scarcity, adopting intensive production systems.

Thus, alternative feeds locally available should be sought so as to lower costs and improve the profitability of the productive sector. The mesquite tree [Prosopis juliflora (SW) D.C.] has proved to be an important alternative feedstuff as it is considered an important energy source in the semi-arid region, and it can replace corn, because its chemical contents include 25-28% glucose, 11-17% starch, 7-11% protein and 14-20% organic acids and pectin, among other substances (Silva et al., 2001). The mesquite tree is a non-oilseed legume species of the family Fabaceae, native to the desert of Piura in Peru. It was introduced in Brazil and widespread mainly in the Northeast, in cultivated and sub-subsistence populations, and is currently considered as an invasive plant in the Caatinga biome. Prosopis juliflora is naturally present in Mexico, Central America and northern South America (Brazil, Peru, Ecuador, Colombia and Venezuela). The average production of the mesquite fruit in the Brazilian Northeast region is estimated at 6 tons per hectare per year for plantations up to 5 years old, depending on the bioclimatic zone in which the trees are managed. At fifteen years of age, the average production of a mesquite tree can reach 70 kg of pods (Ribas et al., 2009).

Given the constant need to improve animal performance as well as to make the farming activity increasingly competitive, the manufacture of feeds should be constantly optimized. Therefore, the objective of this study was to assess intake, digestibility, ingestive behaviour, and body weight variation in lambs fed pelleted diets using mesquite pod meal as a substitute for ground corn grains at the levels of 0, 30, 60 and 90%, as fed.

Materials and methods

The experiment was conducted at the Sheep Farming sector of the Department of Agricultural and Animal Technology (DTRA) of Universidade Estadual do Sudoeste da Bahia, Itapetinga, Bahia State, Brazil, with geographical coordinates 15°09'07" south latitude and 40°15'32" west longitude. The average annual precipitation, average annual temperature and average height in the region are 800 mm, 27°C and 268 m, respectively. Field data were collected between November 2009 and January 2010.

Twelve Santa Inês×Dorper non-castrated male lambs aged four months on average and with an average body weight of 25.0±1.8 kg at the beginning of the experiment were the animals used in this experiment. The lambs were earmarked, wormed and confined in metabolic cages (1.0x0.80 m) with slatted floor, provided with individual feeding and drinking troughs. Lambs were distributed through three 4×4 balanced Latin Squares, with four treatments and four replicates. The experiment lasted 60 days, consisting of four 15-day periods (ten days to adapt to the diets and five to collect samples). The diets were formulated provide a weight gain rate of 300 g/day, as recommended by NRC (2006) for growing sheep. The treatments consisted of pelleted diets with increasing lev-
els of mesquite pod meal in substitution of ground corn grains (0, 30, 60 and 90%, as-fed basis) in the total diet, which consisted of 30% alfalfa hay and 70% concentrate. The chemical composition of mesquite pod meal used in the experiment was: 927.5 g/kg dry matter (DM), 958.3 g/kg organic matter (OM), 78.2 g/kg crude protein (CP), 16.4 g/kg ether extract (EE), 296.5 g/kg neutral detergent fibre (NDF), 241.5 g/kg acid detergent fibre (ADF), 25.0 g/kg neutral detergent insoluble nitrogen, 17.0 g/kg acid detergent insoluble nitrogen, 45.2 g/kg lignin, 567.2 g/kg non-fibrous carbohydrates, 863.7 g/kg total carbohydrates and 41.7 g/kg mineral matter as published by Pereira et al. (2013). Table 1 shows the ingredient proportions and chemical composition of the experimental diets. The pelleted feeds were produced by RIOCON® (Fazendas Reunidas Rio de Contas Ltda, Bahia, Brazil).

The diets were offered ad libitum twice daily, at 07h00 and 15h00, so as to allow for 5 to 10% of leftover feed. The water was always changed in the morning and refilled in the afternoon. To quantify and evaluate the voluntary intake, the feed offered and the leftover feed were weighed during the five sampling days of each experimental period. Voluntary intake was calculated as the difference between the feed supplied and left over. The animals were weighed at the beginning and end of each experimental period to determine the variation in body weight, which was calculated as the difference of weight between both weighing days divided by the number of days in the period. During the sampling period, from the 11th to the 15th day in each experimental period, samples of the feed supplied and left over by each animal were collected daily, conditioned in plastic bags and stored at -20°C for laboratory analysis later on. Samples of the feed offered and the left over by each animal were ground in a knife mill (1 mm mesh sieve), and DM, OM, CP, EE, ND, NDF, ADF, neutral detergent insoluble protein (NDIP), acid detergent insoluble protein (ADIP) and lignin (H2SO4 72% p/p) concentrations were determined according to the procedures described in Silva and Queiroz (2002). The concentration of neutral detergent fibre free of ash and protein (NDFap) was obtained as recommended by Mertens (2002).

Table 1. Composition and concentration of nutrients in the experimental diets.

| Ingredients, g/kg DM      | 0       | 30      | 60      | 90      |
|---------------------------|---------|---------|---------|---------|
| Corn grain                | 480.0   | 336.0   | 192.0   | 48.0    |
| Mesquite pod meal         | 0.0     | 144.0   | 288.0   | 432.0   |
| Soybean meal              | 210.0   | 210.0   | 210.0   | 210.0   |
| Alfalfa hay               | 300.0   | 300.0   | 300.0   | 300.0   |
| Mineral mix°              | 10.0    | 10.0    | 10.0    | 10.0    |
| Total                     | 1000    | 1000    | 1000    | 1000    |
| Nutrients, g/kg DM        |         |         |         |         |
| Dry matter                | 891.1   | 896.0   | 893.3   | 898.4   |
| Organic matter            | 936.0   | 932.0   | 927.0   | 929.0   |
| Crude protein¹            | 214.5   | 241.8   | 228.7   | 218.9   |
| NDIP                      | 88.8    | 145.7   | 175.9   | 199.8   |
| ADIP                      | 14.4    | 14.6    | 16.3    | 15.4    |
| Ether extract             | 139.8   | 130.2   | 127.0   | 112.3   |
| Total carbohydrates       | 583.6   | 559.5   | 571.3   | 598.0   |
| Non-fibrous carbohydrates | 263.9   | 224.1   | 215.8   | 245.5   |
| NFC                       | 292.6   | 265.6   | 265.2   | 265.8   |
| Neutral detergent fibre   | 319.7   | 335.4   | 352.4   | 355.6   |
| NDFap                     | 291.0   | 293.9   | 302.2   | 306.1   |
| Acid detergent fibre      | 115.0   | 173.7   | 209.1   | 229.6   |
| Lignin                    | 28.62   | 42.0    | 48.8    | 50.95   |
| Mineral matter            | 57.3    | 66.1    | 70.4    | 70.6    |

NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein; NFC, non-fibrous carbohydrates corrected for ash and protein; NDFap, neutral detergent fibre free of ash and protein.

¹Mineral mix composition: Zinc, 3800.00 mg; Sodium, 47.00 g; Manganese, 1300.00 mg; Cobalt, 40.00 mg; Iron, 1800.00 mg; Copper, 590.00 mg; Sulfur, 18.00 g; Selenium, 15.00 mg; Iodine, 80.00 mg; Chromium, 20.00 mg; Molybdenum, 300.00 mg; Calcium, 120.00 g; Fluor (max.), 870.00 mg; Phosphorus, 87.00 mg; °Values as g/kg of crude protein.

Hall (2003): NFCap (%DM)=(100-%NDFap-%CP-%EE-%ash). The levels of total digestible nutrients (TDN) were calculated according to Weiss et al. (1990), using the following equation: TDN (%)=DCP+2.25 DEE+TDC, in which: DCP, digestible crude protein; DEE, digestible ether extract; and TDC, total digestible carbohydrates. To evaluate the apparent digestibility of dry matter, the dry matter intake from the 11th to 15th days and the faecal excretion of DM from the 13th to the 15th days of each experimental period were calculated. Faeces were collected in each period, per animal, using Nappa-leather collection bags adapted to animals. Faeces were weighed in the morning and afternoon, and aliquots of approximately 10% of the total were pre-dried and ground in a knife mill with a 1.0 mm mesh sieve, to subsequently form composite samples for each animal per day. Ingestive behaviour was assessed on the 12th day of each experimental period and the animals were visually observed precisely every 10 min, for 24 h, to determine the time spent feeding, ruminating and at rest (idle). These activities were recorded in turns by trained observers who were positioned strategically so as not to disturb the animals. On the same day, the number of cud chews (NCC; n/cud) and the time spent rumi-
nating each cud (s/cud) were counted using a
digital stopwatch. To obtain the average num-ber and time of chews, three cuds were
observed in three different periods of the day
(10h-12h; 14h-16h and 18h-20h). The time and
number of cuds were calculated per cud per
animal. Feed and rumination efficiencies,
expressed as g DM/hour and g NDF/hour, were
obtained by dividing the average daily intakes
of DM and NDF by the total time spent feeding
and/or ruminating in 24 h, respectively. It
should be noted that the intake of dry matter
and NDF used for the calculation of the effi-
ciencies refer to the day when feeding behav-
ior was assessed. These and other variables
obtained in this experiment, such as the num-er of cuds ruminated per day (NRC), total
chewing time (TCT) and the number of cud
chews per day (NCC), were obtained accord-
ting to the methodology described by Bürger et al.
(2000) and Polli et al. (1996).

The dependent variables were assessed by
analysis of variance and regression, using the
MIXED procedure of SAS (2006). The criteria
used to select the regression model were the
coefficient of determination (R2) and the sig-
nificance observed by the F test at 5% probabi-
licity. The variables were analyzed using the fol-
lowing statistical model:

\[ Y_{ijkl} = \mu + L_{Si} + T_{j} + (P/LS)_{ik} + (C/LS)_{il} + LS_{i} + T_{ij} \times \epsilon_{ijkl} \]

where: \( Y_{ijkl} \) observation on lamb l, subjected to
treatment j, in period k, in Latin square i;
\( \mu \), overall mean effect; \( L_{Si} \) effect of Latin square i,
where i=1, 2; \( T_{j} \), effect of treatment j, where
j=1, 2, 3, 4; \( (P/LS)_{ik} \), effect of period k within
Latin square i, where k=1, 2, 3, 4; \( (C/LS)_{il} \),
effect of lamb l within Latin square i, where
l=1, 2, 3, 4; \( LS_{i} \), effect of interaction
between Latin square i and treatment j;
\( \epsilon_{ijkl} \), random error associated with each observa-
tion, assumed NID (0, \( \sigma^{2} \)).

### Results and discussion

Dry matter intake was not influenced
\((P>0.05)\) by the inclusion of mesquite pod meal
in the diet (Table 2), with mean values of 1.33
kg/day, 41.52 g/kg of body weight (BW) or 98.43
g/kg of BW \(^{0.75}\). The results of this study are con-
sistent with those found by Pereira et al.
(2013), who observed no difference in DM
intake evaluating the replacement of corn by
mesquite meal at the levels of 0.0, 33.3, 66.7
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### Table 2. Least square means for intake of dry matter and nutrients in lambs fed mesquite pod meal in substitution of corn in pelleted diets.

| Substitution level, % (as fed) | SEM | L  | Q  | C  |
|-------------------------------|-----|----|----|----|
| **Intake, kg/day**            |     |    |    |    |
| DM                            |     |    |    |    |
| 0    | 1.30 | 1.34 | 1.36 | 1.33 | 0.05 | 0.380 | 0.506 | 0.306 |
| 30   | 1.21 | 1.25 | 1.26 | 1.23 | 0.05 | 0.482 | 0.016 | 0.407 |
| 60   | 0.277| 0.326| 0.305| 0.290| 0.01 | 0.014 | 0.002 | 0.056 |
| 90   | 0.178| 0.173| 0.170| 0.146| 0.006| 0.025^2| 0.536 | 0.309 |
| OM                            |     |    |    |    |
| CP                            |     |    |    |    |
| EE                            |     |    |    |    |
| NDFap                         |     |    |    |    |
| NFC                           |     |    |    |    |
| TC                            |     |    |    |    |
| MM                            |     |    |    |    |
| TDN                           |     |    |    |    |
| **Intake, g/kg BW**           |     |    |    |    |
| DM                            |     |    |    |    |
| 0    | 40.23| 41.55| 42.19| 42.11| 4.69 | 0.188 | 0.406 | 0.221 |
| 30   | 37.70| 38.72| 39.03| 39.12| 4.38 | 0.292 | 0.488 | 0.350 |
| 60   | 8.56 | 10.14| 9.44 | 9.22 | 1.12 | 0.001 | 0.000^3| 0.018 |
| 90   | 5.57 | 5.40 | 5.30 | 4.70 | 0.64 | 0.012^2| 0.396 | 0.155 |
| OM                            |     |    |    |    |
| CP                            |     |    |    |    |
| EE                            |     |    |    |    |
| NDFap                         |     |    |    |    |
| NFC                           |     |    |    |    |
| TC                            |     |    |    |    |
| MM                            |     |    |    |    |
| TDN                           |     |    |    |    |
| **Intake, g/kg \(^{0.75}\)** |     |    |    |    |
| DM                            |     |    |    |    |
| 0    | 95.34| 98.77| 100.32| 99.30| 8.57 | 0.214 | 0.396 | 0.219 |
| 30   | 89.33| 92.94| 92.95| 92.27| 8.01 | 0.312 | 0.467 | 0.334 |
| 60   | 20.50| 24.09| 22.45| 21.72| 2.09 | 0.000^1| 0.002 | 0.018 |
| 90   | 13.19| 12.81| 12.52| 10.99| 1.19 | 0.015^3| 0.459 | 0.199 |
| OM                            |     |    |    |    |
| CP                            |     |    |    |    |
| EE                            |     |    |    |    |
| NDFap                         |     |    |    |    |
| NFC                           |     |    |    |    |
| MM                            |     |    |    |    |
| TDN                           |     |    |    |    |

L, linear; Q, quadratic; C, cubic; DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDFap, neutral detergent fibre free of ash and protein; NFC, non-fibrous carbohydrates; MM, mes-
quito meal; TDN, total digestible nutrients; BW, body weight. Regression equations are as follows: 1

\[ \bar{Y} = (1.16 \pm 0.03)^* + (0.0046 \pm 0.002) X + (0.00005 \pm 0.00002) X^2 + (0.0031 \pm 0.0007)^* + (0.00008 \pm 0.00004) X^3 \]

\[ \bar{Y} = (0.178 \pm 0.005)^* + (0.0033 \pm 0.0009) X + (0.0075 \pm 0.0001) X^2 + (0.0004 \pm 0.00002) X^3 \]

\[ \bar{Y} = (8.49 \pm 0.54)^* + (0.06 \pm 0.03) X + (0.0006 \pm 0.0001) X^2 \]

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\[ \bar{Y} = (5.73 \pm 0.20)^* + (0.0022 \pm 0.0004) X + (0.13 \pm 0.01) X^2 + (0.038 \pm 0.013) X^3 + (0.13 \pm 0.015) X^4 \]

\[ \bar{Y} = (28.22 \pm 1.09)^* + (0.12 \pm 0.05) X^2 + (0.04 \pm 0.01) X^3 + (0.01 \pm 0.01)^* + (0.05 \pm 0.01)^* \]

\[ \bar{Y} = (28.22 \pm 1.09)^* + (0.12 \pm 0.05) X^2 + (0.04 \pm 0.01) X^3 + (0.01 \pm 0.01)^* + (0.05 \pm 0.01)^* \]

\[ \bar{Y} = (28.22 \pm 1.09)^* + (0.12 \pm 0.05) X^2 + (0.04 \pm 0.01) X^3 + (0.01 \pm 0.01)^* + (0.05 \pm 0.01)^* \]
and 100% in diets for goats in the first third of lactation. The control of DM intake is deter-
mined primarily by the rumen being physically filled in the case of diets with high forage lev-
els, or by chemotactic mechanisms in high-
energy diets (Waldo, 1986). In the present
study, because of the high level of concentrate
feeds in the diets (Table 1) and the reduced
particle size of the alfalfa hay to make the feed
pellets, the control of intake was probably deter-
mined first by chemotactic mechanisms, given
that concentrates and/or finely ground forage
promote an increase in passage rate which
reduces the time of permanence of the digesta
in the rumen. With regard to OM intake, there
were significant differences among treat-
ments, expressed as g/day. Based on the quad-
ratic regression, maximum OM intake was esti-
mated to occur when the level of mesquite pod
meal (MPM) was 46%. The various expressions
of CP intake changed (P<0.05) as a result of
the levels of MPM inclusion as substitute for
ground corn grain (Table 1). The average
according to the level of substitution for
intake of CP was higher than 167 and 191 g
CP/day recommended by the NRC (1985) for
sheep with 20 and 30 kg of body mass, respec-
tively. The estimated maximum CP intake (334
g/day) occurred when the level of substitution
of corn grain for MPM was 50% of the final diet
composition.

Lambs fed diets with higher levels of MPM
had lower EE intake (Table 2); this behaviour
can be explained by the concentration of this
nutrient in the diet, which decreased with
inclusion of MPM, which in turn has a lower
concentration of EE in its composition com-
pared with corn. This was also demonstrated
by Pereira (2013), who evaluated the EE intake
by goats fed different levels of substitution (0.0,
33.3, 66.7 and 100%, as-fed basis) of corn for
mesquite pod meal. The levels of MPM addition
had significant effects on NDFap intake,
expressed as kg/day, which increased linearly
(Table 2). The corn and mesquite, assessed
herein, have different compositions with
regard to NDF, with 13.98 and 28.79%, respec-
tively (Valadares Filho et al., 2006). Therefore,
the results obtained for this variable were
already expected, since this difference in the
diet remained. Thus, as the levels of MPM in
the diets increase, the intake of this nutrient
does likewise. Like DM intake, the intakes of
TC and TDN (kg/day) did not present any differ-
ence when the ground corn grains were substi-
tuted for MPM at different levels. The similarity
in TDN intake is explained by the no-variation
verified in DM intake. The total digestibility
coefficients of DM, OM, EE, NDF, NDFap, TC
and the level of TDN decreased linearly, where-
as those of CP and NFC exhibited quadratic
behaviour (Table 3). Although there was no sig-
nificant difference among diets for DM intake
(Table 2), its digestibility coefficient decreased
linearly (P<0.05) as the levels of substitution of
corn for MPM increased. This effect was caused
by the diminution of the activities involved in
the rumination process as a consequence of
lower physical effectiveness of the fibre (feed
pellets); thus, we found that this fact might
have been instrumental in decreasing DM
digestibility by increase in the passage rate.

The organic-matter digestibility coefficient
decreased linearly as the MPM was included in
the experimental diets. This decrease was
probably due to the differences in ADF levels of
the experimental diets (Table 1), because this
component is directly related to the digestibili-
ty of the material. The linear decrease
(P<0.05) in EE digestibility was followed by a
linear reduction (P<0.05) in EE intake. The
lower digestibility observed for the diet con-
taining 90% of MPM can be justified by the
reduced proportion of EE in the dry matter
(Table 1), which caused the intake to decrease
(Table 2), thereby reducing the digestibility
efficiency (Table 3). This fact can be
explained by the increased fecal metabolic EE,
consisting of digestive-tract secretions and of
the material produced by microbial fermenta-
tion (Detmann et al., 2006), which decreases
the coefficient of digestibility, calculated as the
intake of EE minus its fecal excretion, divided
by its intake. The digestibility of NDF and TC
also decreased linearly as the levels of MPM in
the diet were increased. Figueiredo et al.
(2007) reported that MPM contains a greater
participation of fibre in the carbohydrate con-
tent and this tends to reduce digestibility, in
relation to corn. In the present study, we could
observe that the diet digestibility values when
MPM replaced corn were consistent with the
statements of these authors. However, the NDF
digestibility coefficient exhibited similar val-
ues to those reported by Rodrigues et al.
(2008), which varied between 48 and 61% in
diets for confined sheep fed high levels of con-
centrate (90%). The levels of TDN in the diet,
which decreased (P<0.05) linearly with the
substitution of ground corn grain for MPM.

This can be explained by the significant reduc-
tion in the digestibility of dry matter and other

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**Table 3. Least square means for the digestibility coefficients of dry matter and nutrients in lambs fed mesquite pod meal in substitution of corn in pelleted diets.**

| Item     | Substitution level, % (as fed) | SEM  | P       |
|----------|-------------------------------|------|---------|
|          | 0                             | 30   | 60      | 90     |
| DM       | 76.96                         | 75.52| 71.56   | 70.49  |
| OM       | 75.69                         | 75.11| 69.34   | 68.94  |
| CP       | 75.79                         | 78.46| 76.46   | 79.24  |
| EE       | 76.49                         | 74.64| 70.99   | 67.80  |
| NDF      | 65.18                         | 61.09| 51.51   | 50.19  |
| NDFap    | 66.59                         | 62.60| 57.76   | 52.83  |
| NFC      | 95.95                         | 94.59| 92.89   | 94.77  |
| TC       | 74.50                         | 71.62| 65.68   | 64.16  |
| TDN      | 83.82                         | 80.96| 75.36   | 72.87  |

L, linear; Q, quadratic; C, cubic; DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; NDFap, neutral detergent fibre free of ash and protein; NFC, non-structural carbohydrates; TC, total carbohydrates; TDN, total digestible nutrients. Regression equations are as follows: Y=-(79.21±0.71)*(0.11±0.01)*X; Y=-(79.93±0.35)*(0.04±0.02)*X; Y=-(78.94±0.71)*(0.11±0.01)*X; Y=-(76.99±0.84)*(0.04±0.01)*X; Y=-(73.37±0.59)*(0.18±0.01)*X1; Y=-(86.64±0.77)*(0.18±0.01)*X2; P<0.001; **P<0.01; ***P<0.05; ****P<0.05.
nutrients, which was lower for the treatments with higher percentages of mesquite pod meal (Table 3) mainly for the nutritional component ether extract.

According to the fitted equation, maximum CP and NFC digestibilities were estimated at 28.6 and 45.0% of substitution for MPM in the experimental diets. However, the values found for NFC digestibility are considered high, although desirable, because this fraction is easily degraded in the rumen environment. Table 4 displays the mean values for ingestive behaviour as well as regression equations. No significant effect was observed for feeding time (FT) as a result of different MPM levels in the experimental diets, averaging 134.8 minutes/day (Table 4). Because of the particle size, pelleted diets are easily assimilated by the animals, which take less time to consume them; therefore, the feed characteristics may have contributed to the absence of difference in the time spent on ingestion. Rumination time (RT) increased linearly with the levels of mesquite pod meal addition, because of the higher levels of NDF provided by the high participation of this ingredient in the diet. Changes in the time spent feeding and ruminating have been commonly observed in studies in which experimental diets had different fibre levels (Beauchemin, 1994; Carvalho et al., 2006). But the time spent idle (IT) increased linearly as the levels of MPM in substitution of corn were increased. This was most likely because rumination times exhibited inverse responses. However, in the present study, the values found for the time spent feeding and ruminating were reduced, and the idle time (min) was increased, probably due to the use of pelleted feed (physically effective fibre size) and the high level of concentrate in the diet. The total chewing time (TCT) (Table 4), expressed as hours/day, was not influenced by MPM levels in the diets, probably because of the similar particle sizes in the diets. However, the number of ruminated cuds (NRC) increased linearly along with the MPM levels. This variable is dependent on rumination time and the time spent ruminating each cud, and the fact that there was variation in these times explains the differences in NRC among diets. Similarly, the number of cud chews (NCC) per day rose linearly as the levels of MPM were increased, and this may be related to the increase in the number of ruminated cuds per day. Mean values for feeding efficiency (g DM/hour and g NDF/hour), displayed in Table 4, did not differ either. This fact was as a response to similarities in the dry matter intake observed for these diets (Table 2). Rumination efficiency (g DM/hour and g NDF/hour) was negatively influenced by inclusion of MPM in the diet. According to Van Soest (1994), the level of fibre and the physical form of the diet are the main factors affecting rumination time. Since the diets exhibited increase in the NDF levels, rumination efficiency was affected, because according to Dado and Allen (1995), the number of rumination periods increases according to the level of fibre in the diet, which reflects in the need to process the rumen digesta in order to improve the digestive efficiency. No such fact was verified in the present experiment, probably because of the low physical effectiveness of the fibre with reduced particle size.

Table 4. Least square means of the ingestive behaviour of lambs fed mesquite pod meal in substitution of corn in pelleted diets.

| Substitution level, % (as fed) | SEM | P  |
|-------------------------------|-----|----|
|                               | L   | Q  |
| FT                            | 169min12s 170min48s 165min00s 159min12s | 18.72 | 0.66 | 0.936 | 0.842 |
| RT                            | 116min36s 139min12s 181min36s 195min12s | 14.86 | 0.04* | 0.470 | 0.042 |
| IT                            | 19h16min 18h50min 18h15min 18h7min | 18.86 | 0.042 | 0.579 | 0.043 |
| TCT, day                      | 4h46min 5h10min 5h46min 5h43min | 0.28 | 0.10 | 0.485 | 0.085 |
| NRC, n/day                    | 158 198 226 262 | 27.78 | 0.02* | 0.279 | 0.069 |
| NCC, n/day                    | 9.338 1.175 14.519 14.667 | 1.608 | 0.05* | 0.393 | 0.073 |

Feed efficiency

| g DM/hour | 578.9 562.8 633.1 712.3 | 267.3 | 0.54 | 0.888 | 0.635 |
| g NDF/hour| 172.7 184.8 217.4 240.5 | 89.03 | 0.16 | 0.736 | 0.217 |

Rumination efficiency

| g DM/hour | 1031.8 767.4 683.6 547.7 | 318.0 | 0.03* | 0.193 | 0.089 |
| g NDF/hour| 308.0 257.8 189.1 239.6 | 100.9 | 0.05* | 0.447 | 0.302 |

L, linear; Q, quadratic; C, cubic; FT, feeding time; RT, rumination time; IT, idle time; TCT, total chewing time; NRC, number of ruminated cuds; NCC, number of cud chews; DM, dry matter; NDF, neutral detergent fibre. Regression equations are as follows: $\hat{Y} = (0.17x+7.77)^* + (1.24x+16.39)^*; \hat{Y} = (1180.3x+8.9)\times (875x+16.39)^*; \hat{Y} = (223.4x+7.5)^* + (0.42x+0.14)^*; \hat{Y} = (694.3x+49.3)^* + (83.02x+8.05)^*; \hat{Y} = (88.79x+54.15)^* + (22.13x+6.90)^*; \hat{Y} = (290.7x+16.9)^* + (1.9x+0.3)^*.$

*P<0.0001; **P<0.01; ***P<0.05.
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