Mesquite pod (Prosopis juliflora) meal on meat quality of pasture-finishing lambs

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Abstract
This study was carried out to validate the inclusion of up to 750 g/kg of mesquite pod (Prosopis juliflora) meal in the diet and evaluate the effects on carcass characteristics and meat quality for lambs finished in pasture. Forty male, non-castrated, crossbred Santa Inês lambs, with an initial body weight (24.2 ± 3.1 kg), and approximately 120 days old were used. The animals were kept in a total area of 4 ha, divided in four paddocks of 0.62 ha each (10 animals/paddocks), on pastures of Massai (Panicum maximum cv. Massai) with drinkers and feeders during the finishing phase. Dietary treatments based on mesquite pod meal inclusion levels (g/kg of dry matter): CON, without mesquite pod meal; MPM25, 250 g/kg of mesquite pod meal; MPM50, 500 g/kg of mesquite pod meal; and MPM75, 750 g/kg of mesquite pod meal. No treatment effect were detected (P > 0.05) for carcass measures, carcass characteristics, chemical composition of longissimus thoracis muscle, tissue composition, and lipid oxidation. Lamb meat color values, such as lightness (L*) and yellowness (b*), were not affected (P > 0.05) by mesquite pod meal inclusion on the diets, whereas for redness (a*), HUE-angle, and chroma were influenced (P < 0.05). Palmitic acid had a quadratic effect, while oleic acid, eicosatrienoic acid, saturated fatty acids, monounsaturated fatty acids, and PUFA:SFA had a linear course (P < 0.05). In conclusion, the mesquite pod meal can be used as an energy feed source up to 750 g/kg of dry matter in the diet, without changing the carcass characteristics and meat quality of lambs finished in pasture.

Keywords Mesquite pod meal · Nutrition · Pasture · Semiarid · Sheep · Supplementation

Introduction
Sheep meat production in Brazil has grown in the last 10 years, as well as the demand for animal protein in the country’s large urban centers, due to population growth, increased purchasing power of the population, and changes in eating habits (FAO, 2012). This growing demand for healthy products, antibiotic free, care for animal welfare, consequently a product of higher quality, promotes the sheep meat chain to search alternatives that can meet the needs of consumers, without affecting animal productivity with a less impact on the environment, in addition to reducing production costs.

In this context, mesquite pod meal stands out as an ingredient with great potential in animal feed, adapting to the replacement of commonly used concentrated energy feeds (Pereira et al., 2014; Aguiar et al., 2019). It is relevant that fruit collection is carried out in the dry season (autumn–winter), in the off-season of most grains, showing energy, dry matter, and crude protein content close to grain corn.

Another positive point to be considered in this feed is the acceptability by animals, due to large amount of carbohydrates present in the mesquite pod meal (Silva et al., 2001). Furthermore, according to Pereira et al. (2013), the
replacement of corn meal by mesquite pod meal at levels of up to 100% proves to be economically viable.

Coelho et al. (2020) working with pasture sheep, state that the carcass measurement and meat color are not influenced by the use of mesquite pod meal in the diet. However, the alternative ingredient to corn reduced carcass fat without affecting muscle performance. Whereas, the possibility of increasing the proportion of carcass cuts, since the longissimus muscle area increased with gradual inclusion of mesquite pod meal in the diet.

When considering the chemical composition of mesquite pod meal, which is similar to corn, and the viable incorporation into ruminants diet, due it is a low-cost alternative energy ingredient, the objective was to validate the inclusion of up to 75 g/kg of mesquite pod meal in the lambs diet finished in pasture, evaluating the potential use on carcass characteristics and meat quality.

Material and methods

Locality, animal, and diets

The experiment was carried out at cattle sector of Centro de Ciências Agrárias, Ambientais e Biológicas (CCAAB) of Universidade Federal do Recôncavo da Bahia (Cruz das Almas, Bahia, Brazil). On day 1, forty male, non-castrated, 120-day-old approximately, crossbred Santa Inês lambs, were weighed to determine the initial body weight \(\text{initial BW} = 24.2 \pm 3.10\) kg, vaccinated and dewormed prior to start of experiment, which were allocated in an experimental area consisting in a total area of 4 ha, divided in four paddocks of 0.62 ha each (10 animals/paddocks), on pasture of Massai \((Panicum maximum cv. Massai)\) with a total dry forage mass availability of 4052.1 (kg of DM/ha), and provided with drinkers and using a rotated management—four periods of 21 days each, during the finishing phase.

The animals were supplemented in an individual feeding trough (1.0%/body weight; NRC, 2007) once daily (0700 h); throughout the experimental period, all diets being similar in protein content (Table 1). Posteriorly, the animals were taken to the pasture area \((Panicum maximum cv. Massai)\) where they remained grazing freely until 1700 h, and then were directed to a collective pen of 5.0 \(\times\) 5.0 m with concrete floor and free-choice access to water during the next day. The treatments were constituted by four different inclusion levels of mesquite pod meal included: CON, without mesquite pod meal; MPM25, 250 g/kg of mesquite pod meal; MPM50, 500 g/kg of mesquite pod meal; and MPM75, 750 g/kg of mesquite pod meal.

Lambs showed an average daily gain of 0.07, 0.10, 0.09, and 0.09, finished on their respective four dietary treatments CON, MPM25, MPM50, and MPM75 for 84-day experimental period until the animals reached a mean final body weight of 29.7, 32.1, 33.8, and 33.1 kg, respectively. Upon arrival the at the slaughterhouse, animals were kept in resting pens and were subsequently stunned using electro narcosis in compliance with the slaughter standards of the State Inspection Service legislation in Brazil (Brazil, 2000). After slaughter, the carcasses were identified, weighed, and chilled for 24 h at 4 °C, for posteriorly data collection, such as carcass measures, carcass characteristics, chemical composition of longissimus thoracis muscle, tissue composition, color, and lipid oxidation.

### Table 1 Composition of ingredients and the diets fed to Santa Inês lambs (g/kg of DM)

| Ingredients                  | DM  | OM  | CP  | EE  | NDF | CELL | HEMI | LIG  | Ash | NFC | TDN | ME (kcal/kg) |
|-----------------------------|-----|-----|-----|-----|-----|------|------|------|-----|-----|-----|--------------|
| Massai grass                | 368 | 915 | 95.4| 16.1| 748 | 298  | 380  | 69.1 | 85.3| 54.7| 573| 2,102        |
| Soybean meal                | 909 | 932 | 386 | 15.1| 118 | 14.5 | 87.4 | 15.8 | 67.5| 414| 846| 3,317        |
| Ground corn                 | 908 | 980 | 102 | 44.8| 109 | 34.8 | 52.3 | 22.0 | 20.1| 723| 826| 3,228        |
| Mesquite pod meal           | 909 | 932 | 386 | 15.0| 118 | 14.5 | 87.4 | 15.8 | 67.5| 414| 846| 3,317        |
| Mineral salt\(^2\)          | 974 | 61.1| -   | -   | -   | -    | -    | -    | 913 | -  | -   | -            |
| CON                         | 912 | 924 | 237 | 72.6| 148 | 26.3 | 148  | 59.0 | 75.9| 466| 840| 3,291        |
| MPM25                       | 919 | 922 | 194 | 68.1| 188 | 56.3 | 188  | 65.4 | 77.7| 473| 837| 3,277        |
| MPM50                       | 926 | 910 | 215 | 56.8| 229 | 81.6 | 229  | 70.5 | 90.3| 408| 838| 3,282        |
| MPM75                       | 933 | 905 | 185 | 50.8| 270 | 110  | 270  | 76.6 | 94.5| 399| 836| 3,273        |

\(^1\)Metabolizable energy was calculated using the equations proposed by NRC (2001)

\(^2\)Mineral salt composition (kg): calcium, 50 g; magnesium, 57 g; sodium, 81 g; sulfur, 3.75 g; cobalt, 20 mg; copper, 500 mg; iodine, 25 mg; manganese, 1500 mg; selenium, 10 mg; zinc, 2000 mg; vitamin A, 400,000 IU; vitamin D3, 50,000 IU; vitamin E, 750 IU
Carcass measures

Thoracic depth, rump width, external carcass length, internal carcass length, shank thickness, internal leg length, and external leg length were obtained according to the methodology described by Osório and Osório (2005). Through these measures, the carcass compactness index and the leg compactness index were calculated (Osório and Osório, 2005), using to the equations described below:

\[
CCI = \frac{CCW}{CL} \\
LCI = \frac{RW}{ILL}
\]

where \( CCI \) = carcass compactness index; \( CCW \) = cold carcass weight; \( CL \) = carcass length; \( LCI \) = leg compactness index; \( RW \) = rump width; and \( ILL \) = internal leg length.

Carcass characteristics

At slaughter time and 24 h postmortem, the Longissimus dorsi pH was measured using a digital pH meter (Hanna – HI99163, Romania—Europe) with a penetration electrode placed at the point of the 3rd lumbar vertebra. The pH meter was calibrated at 20 °C using standard pH 4.0 and 7.0 buffers (Valero et al., 2014).

Longissimus dorsi muscle area and thickness of subcutaneous fat were measured at 24 h postmortem in the 12th rib by photographic images. Images were taken with aid of a digital camera in a straight line over the samples, forming an angle of 90°. An object of known length was placed next to samples, to aid analysis by the ImageJ software.

Texture measurement of the previously cooked steaks was analyzed using a Stable Micro Systems TA.XTPlus (Texture Technologies Corp., Serial Number 41288, Godalming, Surrey, UK) texture analyzer with a Warner–Bratzler blade, according to Honikel (1998). The steaks were analyzed using a Stable Micro Systems TA.XTplus (Texture Technologies Corp., Serial Number 41288, Godalming, Surrey, UK) texture analyzer with a Warner–Bratzler blade, according to Honikel (1998). The steaks were cooked in a pre-heated grill (Grill Philco Jumbo Inox, Philco SA, Brazil) at 200 °C until an internal temperature of 72 °C was reached, which was monitored using an internal thermocouple (Incoterm, 145 mm, Incoterm LTDA, Brazil). The sample was then removed from the heat and left at ambient temperature to cool. Once the steak reached 25 °C, each steak was weighed and the

cooking losses calculated as the percentage difference in weight before and after cooking, as shown in the equation below:

\[
CL = \frac{SWBC - SWAC}{SWAC} \times 100
\]

where \( CL \) = cooking losses; \( SWBC \) = sample weight before cooking; and \( SWAC \) = sample weight after cooking.

The water-holding capacity was determined by the methodology described by Nakamura (1985), which the samples were packed on filter paper (approximately 1 g), and centrifuged for 4 min at 1500 × g. Subsequently, the filter paper was discarded and the samples were oven dried at 70 °C for 12 h. The water-holding capacity was determined by the equation:

\[
WHC = \frac{SWC - DSW/IW}{SWC} \times 100
\]

where \( WHC \) = water-holding capacity; \( SWC \) = sample weight after centrifugation; \( DSW \) = dry sample weight; and \( IW \) = initial weight.

Chemical analysis of meat samples

To determine chemical composition, the samples were homogenized in a multiprocessor until a homogeneous mass was obtained. Moisture (ID 950.46B) content was determined by drying in an oven at 105 °C until a constant weight was obtained (AOAC, 2005); ash content was measured by combustion at 550 °C for 16 h according to method ID 942.05 (AOAC, 2005); total fat was extracted by the Soxhlet method ID 960.39 (AOAC, 2005); and the crude protein was measured using the Kjeldahl method ID 992.15 (AOAC, 2005).

Carcass tissue composition

After 24 h postmortem, the carcass tissue composition was determined by the dissection technique between the 12th and 13th ribs, with the aid of a bistoury according to the methodology of Menezes et al. (2015). Muscle, fat (subcutaneous and inter-muscular), and bone weights were obtained, expressed as a percentage of entire weight of rib sampled.

Instrumental meat color

The color was evaluated after 30 min of exposure to oxygen at 1 day of display, by using the CIELab system with a Minolta CR-400 Chroma meter (Japan) (with a 10° view angle, D65 illuminant, 8 mm of aperture with a close cone). Six measurements at randomly selected points were recorded per sample (longissimus muscle, between the 12th and 13th ribs), obtaining lightness (L*), redness (a*) and yellowness (b*). Chroma and hue values were determined according to
the methodology described by Ramos and Gomide (2012), using to the equations described below:

\[
\text{Chroma} = \left( \sqrt{a^* + b^*} \right)
\]

\[
H^0 = (\arctan(b^*/a^*))
\]

where: \(a^*\) = redness; \(b^*\) = Yellowness; and \(H^0\) = hue angle.

Lipid oxidation

The malondialdehyde (MDA) content in meat was quantified using the thiobarbituric acid reactive substances (TBARS) assay as was adapted by Vital et al. (2016). The sample (5 g) was mixed with trichloroacetic acid (10 mL), homogenized using an Ultra-Turrax, and then centrifuged (4000 \(\times\) g) at 4 °C for 15 min. The supernatant was filtered and mixed with TBARS reagent (1:1 v/v). The mixture was boiled (100 °C) for 15 min, cooled then the absorbance measured at 532 nm against an MDA standard. Results were expressed as mg MDA/kg of meat. The assay was performed at 1, 7, and 14 days of display.

Fat acid profile

Fatty acid methyl esters by transesterification of triglycerides acids were obtained in a solution of n-heptane and KOH/methanol (ISO, 1978). The analysis of the methyl esters of the fatty acid were carried out in the gas chromatograph 14-A (Shimadzu Corp, Nakagyoku, Kyoto, Japan) equipped with a flame ionization detector and fused silica capillary column with 100-m length, 0.25-mm inner diameter and 0.20 mm in polisiloquinoxanocyanoalkyl, CP-Sil 88 (Chrompack, Santa Clara, CA, USA). To record the concentrations of fatty acids, the device was coupled to a GC-300 Processor Integrator (CG Scientific Instruments, Woburn, MA, USA). The conditions adopted in chromatographic separation process, and the quantification of fatty acids were performed using correction factors for peak area, according to Goes et al. (2018).

Statistical analyses

Data were analyzed by using the ANOVA procedure of SAS (SAS, 2004) to perform a randomized complete experiment with four treatments and ten replications, using the model:

\[
Y_{ij} = \mu + ai + \epsilon(ij)
\]

where \(Y_{ij}\) = dependent variables; \(\mu\) = constant general; \(ai\) = effect related to the inclusion level \(i\) \((i = 1, 2, 3, \text{ and } 4)\); and \(\epsilon(ij)\) = random error.

For each studied variable, the mean and standard error of the mean (SEM) were calculated and linear and quadratic regression tests were performed between the supplement treatments \((P \leq 0.05)\).

Results

Carcass measurements and compactness indexes (carcass and leg) were not affected \((P > 0.05)\) by the levels of mesquite pod meal in the supplement (Table 2). There were no differences \((P > 0.05)\) in Longissimus muscle area, thickness of subcutaneous fat, initial pH (at the time of slaughter), final pH (pH 24 h), shear force, losses (cooking and thawing losses), and water-holding capacity (Table 3). Inclusion of mesquite pod meal in the diet

| Parameters                        | CON  | MPM25 | MPM50 | MPM75 | SEM  | L     | Q     |
|-----------------------------------|------|-------|-------|-------|------|-------|-------|
| External carcass length (cm)      | 54.7 | 48.5  | 52.6  | 52.8  | 1.31 | 0.137 | 0.114 |
| Internal carcass length (cm)      | 52.6 | 51.5  | 51.5  | 46.1  | 1.26 | 0.167 | 0.393 |
| External leg length (cm)          | 42.2 | 42.2  | 41.8  | 42.3  | 0.19 | 0.996 | 0.804 |
| Internal leg length (cm)          | 40.7 | 40.5  | 40.5  | 40.6  | 0.19 | 0.626 | 0.754 |
| Thoracic depth (cm)               | 17.5 | 17.3  | 16.7  | 16.8  | 0.14 | 0.383 | 0.759 |
| Rump width (cm)                   | 15.5 | 15.6  | 16.3  | 15.3  | 0.17 | 0.809 | 0.242 |
| Shank thickness (cm)              | 12.1 | 11.6  | 12.2  | 11.8  | 0.13 | 0.521 | 0.089 |
| CCI (kg/cm²)                      | 0.22 | 0.24  | 0.26  | 0.26  | 0.07 | 0.211 | 0.718 |
| LCI (kg/cm²)                      | 0.38 | 0.38  | 0.40  | 0.37  | 0.07 | 0.665 | 0.296 |

CON = without mesquite pod meal; MPM25 = 250 g/kg of mesquite pod meal; MPM50 = 500 g/kg of mesquite pod meal; MPM75 = 750 g/kg of mesquite pod meal
CCI carcass compactness index, LCI leg compactness index, SEM standard error of the mean, L linear effect, Q quadratic effect
did not affect \((P > 0.05)\) the chemical composition of lamb meat (Table 4). Carcass tissue composition (% muscle, fat, and bone) based on dissection between the 12th and 13th ribs from the carcass were not affected \((P > 0.05\); Table 5). Lightness \((L^*)\) and yellowness \((b^*)\) were not influenced \((P > 0.05)\), whereas the redness \((a^*\) presented decreasing values with the inclusion of mesquite pod meal in the diet \((P < 0.05)\). However, chroma and \(h^0\) values showed a linear course \((P < 0.05\); Table 6). Meat lipid oxidation at 1, 7, and 14 days of display was not affected \((P > 0.05\); Table 7) at none of maturation times. Fatty acid profile, the palmitic acid \((C16:0)\) had a quadratic effect, while oleic \((C18:1)\) and eicosatrienoic \((C20:3\omega3)\) acids had a linear effect \((P < 0.05)\). However, sum of fatty acids—saturated fatty acids, monounsaturated fatty acids, and PUFA:SFA had a linear course \((P < 0.05\); Table 8).

Table 3 Carcass characteristics of *longissimus* samples from Santa Inês lambs supplemented or not with mesquite pod meal during the finishing phase on pasture

| Parameters               | CON     | MPM25   | MPM50   | MPM75   | SEM    | L      | Q      |
|--------------------------|---------|---------|---------|---------|--------|--------|--------|
| pH abate                 | 7.38    | 7.39    | 7.32    | 7.33    | 0.04   | 0.612  | 0.873  |
| pH 24 h                  | 5.54    | 5.51    | 5.52    | 5.56    | 0.03   | 0.259  | 0.189  |
| LMA \((\text{cm}^2)\)    | 3.90    | 4.34    | 4.45    | 4.16    | 0.13   | 0.713  | 0.582  |
| Fat thickness \((\text{cm})\) | 0.10    | 0.12    | 0.15    | 0.13    | 0.02   | 0.296  | 0.858  |
| Shear force \((\text{kgf/cm}^2)\) | 2.36    | 2.34    | 2.38    | 2.34    | 0.03   | 0.632  | 0.538  |
| WHC \((\text{mL/100/g})\) | 53.2    | 53.8    | 53.3    | 54.1    | 0.38   | 0.834  | 0.393  |
| Cooking losses (%)       | 22.5    | 20.6    | 20.5    | 21.0    | 0.61   | 0.562  | 0.396  |
| Thawing losses (%)       | 4.14    | 4.70    | 4.56    | 4.37    | 0.05   | 0.186  | 0.695  |

CON = without mesquite pod meal; MPM25 = 250 g/kg of mesquite pod meal; MPM50 = 500 g/kg of mesquite pod meal; MPM75 = 750 g/kg of mesquite pod meal

*LMA* *Longissimus* muscle area, *WHC* water holding capacity, *SEM* standard error of the mean, *L* linear effect, *Q* quadratic effect

Table 4 Chemical composition of *longissimus* samples from Santa Inês lambs supplemented or not with mesquite pod meal during the finishing phase on pasture

| Parameters \((\text{g/kg DM basis})\) | CON     | MPM25   | MPM50   | MPM75   | SEM    | L      | Q      |
|-----------------------------------|---------|---------|---------|---------|--------|--------|--------|
| Moisture                          | 74.3    | 74.7    | 74.8    | 74.4    | 0.10   | 0.158  | 0.269  |
| Ash                               | 1.65    | 1.71    | 1.66    | 1.68    | 0.04   | 0.679  | 0.889  |
| Ether extract                     | 3.00    | 2.99    | 2.99    | 2.99    | 0.01   | 0.222  | 0.409  |
| Crude protein                     | 20.9    | 20.6    | 20.5    | 20.9    | 0.11   | 0.171  | 0.321  |

CON = without mesquite pod meal; MPM25 = 250 g/kg of mesquite pod meal; MPM50 = 500 g/kg of mesquite pod meal; MPM75 = 750 g/kg of mesquite pod meal

*SEM* standard error of the mean, *L* linear effect, *Q* quadratic effect

Table 5 Carcass composition from Santa Inês lambs supplemented or not with mesquite pod meal during the finishing phase on pasture

| Longissimus muscle, %         | CON     | MPM25   | MPM50   | MPM75   | SEM    | L      | Q      |
|--------------------------------|---------|---------|---------|---------|--------|--------|--------|
| Muscle                        | 50.1    | 50.1    | 51.2    | 50.8    | 1.08   | 0.687  | 0.419  |
| Fat                            | 6.06    | 5.68    | 5.88    | 5.47    | 0.19   | 0.216  | 0.856  |
| Bone                           | 43.8    | 43.3    | 42.9    | 43.7    | 1.05   | 0.842  | 0.429  |

CON = without mesquite pod meal; MPM25 = 250 g/kg of mesquite pod meal; MPM50 = 500 g/kg of mesquite pod meal; MPM75 = 750 g/kg of mesquite pod meal

*SEM* standard error of the mean, *L* linear effect, *Q* quadratic effect
Discussion

The similarity in the results for carcass measurements is associated with animals’ homogeneity at the beginning of experiment until the slaughter period. These characteristics are directly related to slaughter weight, animal genotype, and the diet indirectly influences carcass measurements (Bonvillani et al., 2010). Compactness indexes prove that the animals between treatments showed uniformity and a good muscle proportion, which according to Suassuna et al. (2015), the carcass compactness indexes must be equal to and/or greater than 0.20 kg/cm.

*Longissimus* muscle area and thickness of subcutaneous fat are used to predict the amount of muscle and fat present in the carcass, due to positive correlation between them. Thus, the average values for subcutaneous fat thickness of experimental animal carcasses were considered scarce, even for animals of Santa Inês breed, due to their poor deposition (Araújo Filho et al., 2010). However, the recommended for Santa Inês sheep is 0.3 cm of subcutaneous fat thickness (Silva Sobrinho, 2001).

The pH can negatively influence the qualitative characteristics of meat, modifying the appearance, conservation, tenderness, flavor, as well as the nutritional value of the meat (Gomide et al., 2013); However, the average values observed for the present study was 5.53, considered adequate, since the ideal for sheep meat are values between 5.5 and 5.8 (Gois et al., 2017).

Meat samples showed an average of 2.35 (kgf/cm²) for shear force, being considered as very tender meat, according to classification system mentioned by Boleman et al. (1997) in which meat with a shear force between 2.3 and 3.6 (kgf/cm²) is considered extremely tender. Cooking and thawing losses according to Costa et al. (2011), are important characteristics to be measured, as they are associated with the yield at the time of meat preparation, storage, and influenced by the water holding capacity. In its turn, this parameter, according to Zeola et al. (2007), is indicative of losses, and thus, the lower the water holding capacity, the greater the losses due to cooking and nutritional value (soluble proteins, lipids, and minerals).

The reason for similar values for chemical composition is most likely due to the homogeneity of all animals in relation to age, initial body weight, average daily gain, and final body weight. The values referring to moisture, crude protein, ether extract, and ash observed in the present study are match with the values presented by Madruga et al. (2008) and Gois et al. (2017) for lamb meat, which were ~74.5%, 20.7%, 2.99, and 1.67%, respectively. Studies carried out with lambs reported muscle, fat, and bone percentages (Azizi-shotorkhoft et al., 2015), befitting to

| Parameters | CON | MPM25 | MPM50 | MPM75 | SEM | L   | Q   |
|------------|-----|-------|-------|-------|-----|-----|-----|
| L*         | 42.3| 43.7  | 44.1  | 43.6  | 0.33| 0.123| 0.812|
| a*         | 11.9| 11.7  | 11.6  | 10.4  | 0.13| 0.001| 0.736|
| b*         | 11.8| 12.6  | 12.0  | 12.1  | 0.11| 0.722| 0.085|
| Chroma     | 16.8| 17.2  | 15.9  | 16.2  | 0.14| 0.014| 0.143|
| Hue        | 48.4| 49.2  | 47.4  | 44.8  | 0.34| 0.001| 0.273|

Table 6  L*a*b*, chroma and hue values of *longissimus* sample from Santa Inês lambs supplemented or not with mesquite pod meal during the finishing phase on pasture

Table 7  Lipid oxidation (TBARS) expressed as mg malonaldehyde/kg of *longissimus* sample from Santa Inês lambs supplemented or not with mesquite pod meal during the finishing phase on pasture

| Days | CON | MPM25 | MPM50 | MPM75 | SEM | L   | Q   |
|------|-----|-------|-------|-------|-----|-----|-----|
| 1    | 0.59| 0.55  | 0.61  | 0.57  | 0.02| 0.738| 0.167|
| 7    | 0.57| 0.54  | 0.54  | 0.61  | 0.02| 0.991| 0.162|
| 14   | 0.56| 0.58  | 0.52  | 0.59  | 0.02| 0.438| 0.760|

CON = without mesquite pod meal; MPM25 = 250 g/kg of mesquite pod meal; MPM50 = 500 g/kg of mesquite pod meal; MPM75 = 750 g/kg of mesquite pod meal

SEM standard error of the mean, L linear effect, Q quadratic effect

\[ Y = 9.98707 + 0.45656x \]

\[ Y = 15.5102 - 0.4879x \]

\[ Y = 50.36282 - 1.11620x \]
values obtained in this study can be considered normal for these animal categories.

According to Pinheiro et al. (2009), the increase in weight and age at slaughter, promotes the color of lamb meat with a lower lightness (L*) value, due to the greater fat amount and less water contained in the animals’ muscle. Whereas, in the present study, the animals were slaughtered at ~7 months old, showing low carcass fat content, which promoted similarity between treatments for lightness and yellowness (b*). Values observed in this study for lightness, redness (a*), and yellowness are within the standard for sheep breed, according to research described by Bressan et al. (2001), Rodrigues et al. (2008), and Jucá et al. (2016), who report values from 30.1 to 49.5, 8.24 to 23.5, and 3.34 to 13.1, respectively. Chroma and hue are variables influenced by redness value, and thus, we can claim that results found for these characteristics are directly related to effect of mesquite pod meal on redness meat color.

Lipid oxidation for all treatments showed indexes lower the maximum limits established for the perception of oxidative rancidity through the flavor present in the food, which is recommended in 1.0 mg of malonaldehyde/kg of sample (Tarladgis et al., 1960 and Hamling et al., 2008).

Values of C20:3 and monounsaturated fatty acids remained within the standard for meat samples from ruminants fed with oilseeds or their by-products (Goes et al., 2018 and De Araújo et al., 2021). According to Goes et al. (2018) working with levels of replacement of soybean meal by sunflower cake in feeding heifers, found high values for C16:0, while the values of mesquite pod meal treatments in the present study remained low. This is an important result, since C16:0 fatty acid has high

### Table 8

| Items, % | CON | MPM25 | MPM50 | MPM75 | SEM | L | Q |
|---|---|---|---|---|---|---|---|
| **Fatty acid profile** | | | | | | | |
| C10:0 | 0.36 | 0.35 | 0.35 | 0.35 | 0.01 | 0.473 | 0.206 |
| C12:0 | 0.11 | 0.12 | 0.11 | 0.11 | 0.01 | 0.591 | 0.233 |
| C14:0 | 2.26 | 2.29 | 2.26 | 2.27 | 0.02 | 0.989 | 0.681 |
| C16:0<sup>a</sup> | 23.2 | 23.5 | 23.4 | 23.7 | 0.10 | 0.003 | 0.014 |
| C18:0 | 18.2 | 18.2 | 18.3 | 18.3 | 0.02 | 0.224 | 0.325 |
| C20:0 | 0.11 | 0.11 | 0.11 | 0.11 | 0.01 | 0.581 | 0.712 |
| C16:1 | 3.56 | 3.57 | 3.58 | 3.56 | 0.02 | 0.989 | 0.738 |
| C18:1<sup>b</sup> | 44.1 | 43.8 | 43.9 | 43.7 | 0.09 | 0.017 | 0.052 |
| C18:2<sup>a</sup> | 2.49 | 2.41 | 2.46 | 2.40 | 0.02 | 0.057 | 0.157 |
| C18:2CLA | 0.17 | 0.17 | 0.17 | 0.18 | 0.01 | 0.290 | 0.496 |
| C18:3<sup>c</sup> | 0.45 | 0.44 | 0.46 | 0.45 | 0.01 | 0.588 | 0.865 |
| C20:3<sup>d</sup> | 0.11 | 0.11 | 0.11 | 0.10 | 0.01 | 0.028 | 0.089 |
| C20:3<sup>e</sup> | 0.10 | 0.10 | 0.10 | 0.10 | 0.01 | 0.575 | 0.704 |
| C20:4<sup>f</sup> | 0.17 | 0.18 | 0.17 | 0.18 | 0.01 | 0.480 | 0.776 |
| **Sum of fatty acids** | | | | | | | |
| Saturated fatty acids<sup>d</sup> | 44.3 | 44.6 | 44.6 | 44.8 | 0.09 | 0.008 | 0.113 |
| Monounsaturated fatty acids<sup>e</sup> | 47.7 | 47.5 | 47.6 | 47.4 | 0.09 | 0.018 | 0.058 |
| Polyunsaturated fatty acids | 3.50 | 3.43 | 3.47 | 3.42 | 0.03 | 0.159 | 0.356 |
| ω-3 | 0.56 | 0.55 | 0.56 | 0.56 | 0.01 | 0.904 | 0.991 |
| ω-6 | 2.94 | 2.87 | 2.91 | 2.86 | 0.03 | 0.106 | 0.257 |
| ω-6<sup>c</sup>ω-3 | 5.26 | 5.21 | 5.16 | 5.14 | 0.09 | 0.323 | 0.611 |
| **PUFA:SFA<sup>f</sup>** | 0.079 | 0.077 | 0.076 | 0.08 | 0.01 | 0.039 | 0.109 |

CON = without mesquite pod meal; MPM25 = 250 mg/kg of mesquite pod meal; MPM50 = 500 mg/kg of mesquite pod meal; MPM75 = 750 mg/kg of mesquite pod meal

SEM standard error of the mean, L linear effect, Q quadratic effect

<sup>a</sup>Y = 23.22410 + 0.00812 − 0.0000328x<sup>2</sup>

<sup>b</sup>Y = 44.02320 − 0.00401x

<sup>c</sup>Y = 0.10980 − 0.000068x

<sup>d</sup>Y = 44.34010 + 0.00612x

<sup>e</sup>Y = 47.69480 − 0.00399x

<sup>f</sup>Y = 0.07854 − 0.0000284x
choline levels and provides less action on liver receptors for low-density lipoprotein, and consequently at high dosages in the bloodstream, it harms human health (Goes et al., 2018).

According to Sañudo et al. (2000) and Quiñones et al. (2019), the fatty acid profile in the _Longissimus_ muscle presented a conduct similar to the present study, providing an increase of C18:1 in the meat as the mesquite pod meal was added. The explanation for this event is due to high levels of unsaturated fatty acids present in the mesquite pod meal; when consumed in a diet by ruminants go through the biohydrogenation process, consequently absorbed in the intestine, and incorporated into the tissues. Furthermore, there is a possibility that C18:1 fatty acid is related to action of lipogenic enzymes (Yeom et al., 2005; Quiñones et al., 2019).

De Araújo et al. (2021) working with castor bean meal from the biodiesel process did not observe any difference for saturated fatty acids from meat samples (ruminant animals), whereas, the present results indicate a significant increase in the saturated fatty acids content with addition of mesquite pod meal to lambs diet. However, care for human health has favored debates in recent years regarding the effect of saturated fatty acids, so far there has been no evidence of any correlation with ratio of saturated fatty acids consumed and cardiovascular diseases (Astrup et al., 2011; Li et al., 2015; Praagman et al., 2016).

According to Aksoy et al. (2019) the contents of saturated fatty acids, monounsaturated fatty acids and polyunsaturated fatty acids are used as parameters in determining the nutritional quality of meat intramuscular fat. Consequently, the ratio of polyunsaturated fatty acids and saturated fatty acids is influenced positively or negatively, but according to Department of Health (1994) recommendations, this ratio must be equal to or less than 0.45; medium result of 0.077 found in the present study, proves the meat quality of lambs fed with mesquite pod meal.

In conclusion, the great potential of using mesquite pod (_Prosopis juliflora_) meal as an energetic ingredient in supplements for lambs finished in pasture can be considered, aiming that the carcass characteristics and meat quality were not affected with the inclusion of mesquite pod meal (_Prosopis juliflora_) meal.

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**Data availability** The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate** Not applicable.

**Consent for publication** All authors have given their consent that this work is valid and represent their views of the study, and all authors have given their consent for this work to be published.

**Research involving animals** The Committee for Ethics in the use of Animals (CEUA) of the Universidade Federal do Recôncavo da Bahia approved this experiment (no. 23007.004598/2016–17).

**Informed consent** Not applicable.

**Conflict of interest** The authors declare no competing interests.

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