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Research Article

# Carcass characteristics and fatty acid profile of Santa Inês lamb fed banana leftovers

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**ABSTRACT**: The use of new feed resources, particularly local agroindustrial byproducts, such as banana, may be an option for replacing those traditionally used for sheep feed to reduce production costs. Thus, the aim of this study was to evaluate the dietary effects of replacing corn bran with banana leftovers on performance, carcass, non-carcass components, meat traits, and fatty acid profile of Santa Inês lambs. Twenty-four Santa Inês female lambs with an average weight of 23.73 kg were fed diets containing 60 % coast cross hay and 40 % concentrate (30 % corn bran and 10 % soybean meal). Treatments consisted of corn bran replaced by banana leftovers at rates of 0, 25, 50, and 75 % on a dry matter basis. The experiment lasted 120 days. Animals were slaughtered and carcasses and non-carcass components were evaluated. The half-carcasses were weighed and sectioned into commercial cuts. The 12th and 13th ribs were dissected to collect bones, muscle and fat proportions. Cooking loss, color, shear force and sarcomere length were measured. Fatty acid profiles were obtained by gas chromatography. Hot and cold carcass weight, leg, neck, lung, loin eye area, fat thickness, initial sample weight of the 12th and 13th ribs, fat and bone, presented a negative linear effect of banana leftovers replacing corn in the diet. Loin, fat thickness, cooking loss and carcass redness showed a negative quadratic effect, while full and empty abomasum, full omasum, sarcomere length and yellowness presented a positive quadratic effect. Replacement of up to 75 % of corn bran by banana leftovers did not interfere in the intake, performance, meat traits and the fatty acid profile of lambs. The use of banana leftovers may be an alternative for reducing animal production costs.
**Keywords**: byproducts, meat quality, non-carcass components, sustainability

## Introduction

Brazilian agriculture hits record production levels every year, generating an increasing quantity of agricultural residues and agroindustrial byproducts with high potential for use in ruminant feed (Menezes et al., 2013). This includes leftovers from the horticulture and fruticulture sectors.

The high loss rate during the production and marketing of banana may vary and only 60-70 % of production effectively reaches the consumer's table (Wadhwa et al., 2015). According to IBGE (2016), in 2016, the total area utilized for banana production was 505,079 ha, with a production of 6,799,005 tons. Assuming a 30 % loss, approximately 2,039,702 tons would have been discarded due to a variety of reasons.

The gap between demand and supply of conventional feed resources for feeding livestock on the planet is increasing. To meet this shortfall, feed resources with potential application in ruminant feeding and particularly in the development of fully sustainable food systems have been studied (Amata, 2014). Bananas have been identified as an alternative source of energy for the animal production system (Archimède et al., 2010; Wadhwa et al., 2015). In addition, considering the upward trend in corn prices, the use of byproducts, such as banana, may be an economic alternative for reducing production costs (Almeida et al., 2015).

Therefore, this study aimed at evaluating the effect of replacing corn with banana leftovers in the diet of Santa Inês lambs on performance, carcass and non-carcass components, meat traits and the fatty acid profile of the *Longissimus lumborum* muscle.

## Materials and Methods

Animal care procedures throughout the study followed protocols approved by the Ethics Committee for Animal Use (CEUA) at the University of Brasília, number 44568/2009.

This experiment was carried out in the Federal District, Brazil, at 15°56′ S and 47°56′ W at an altitude of 1080 m. This location has a tropical seasonal climate according to the Köppen classification (Köppen, 2011).

Twenty-four Santa Inês female lambs, with an average age of three months and average body weight of 23.73 ± 0.30 kg were randomly sorted into four groups. The animals were housed in individual pens with individual feeders and water troughs, 14 days before the start of the experiment to adapt the animals to the diet. The experiment lasted 120 days and animals were weighed fortnightly. Average daily gain was calculated as a regression of weights over this period.

Lambs were fed with diets containing 60 % coast cross hay and 40 % concentrate (30 % corn bran and 10 % soybean meal). Treatments consisted of corn bran

replaced by banana leftovers at 0, 25, 50, and 75 % on a dry matter basis (Table 1). The banana leftovers consisted primarily of fruit with physical and mechanical damage at advanced stages of maturation. Banana leftovers were cut lengthwise and then into cubes of 1 $cm^3$ with the use of a chopper and air dried in the shade for 72 h. The diets were formulated according to NRC (2007), a calculation that considers an intake of 3 % of live body weight, and contains 150 g $kg^{-1}$ of crude protein (Table 1). Water and mineral supplement were provided *ad libitum*. Each kg of the mineral supplement contained 82.0 g calcium, 60.0 g phosphorus, 11.7 g sulfur, 132.00 g sodium, 30.00 mg cobalt, 350.00 mg copper, 11.70 mg chrome, 700.00 mg iron, 50.00 mg iodine, 1,200.00 mg manganese, 180.00 mg molybdenum; 15.00 mg selenium, 2,600.00 mg zing, and a maximum of 600.00 mg fluorine. The banana leftovers portion was offered at 08h30, the coast cross hay at 10h30, the concentrate (corn bran and soybean meal) at 11h30 and the mineral salt at 12h00. The diet was offered at different times during the day to ensure maximum consumption of the ingredients by the animals. Waste was removed separately to facilitate intake determination.

The ingredients used in the Santa Inês lambs diets were analyzed for dry matter (DM), crude protein (CP), mineral matter (MM), and ether extract (EE) according to AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (LIG) analysis were performed as described by Van Soest et al. (1991). Total phenols (TPH), total tannin (TAN), and condensed tannin (CTAN) were analysed as described by Xu and Chang (2009) (Table 1).

At the end of the experiment, the lambs were weighed before and after fasting for 24 h to obtain final (LW) and fasting (FLW) live weights, respectively. Animals were slaughtered in a slaughterhouse with Federal Inspection Service subsequent to the fasting period. After they were desensitized, they were bled out, and the following parts weighed separately: skin, head, thoracic organs: lung, heart and trachea as well as abdominal organs: liver, kidneys, rumen, abomasum, reticulum, omasum as well as full and empty intestines to calculate the content of the gastrointestinal tract (GIT). The percentage of carcass constituents was calculated over fasting live weight (FLW).

The carcasses were weighed at slaughter to obtain the hot carcass weight (HCW), chilled at 1 °C for 24 h and then weighed again for determination of cold carcass weight (CCW), weight loss by cooling (HCW-CCW/HCW*100) and cold carcass kill-out (CCW/FLW*100).

**Table 1** – Proportion (% of dry matter), ingredients bromatological composition (g $kg^{-1}$ of dry matter) and diet chemical composition (g $kg^{-1}$ of dry matter) used in the diet of Santa Inês.

| Levels of replacement (%) | Ingredients | | | |
|---|---|---|---|---|
| | Banana leftovers | Corn bran | Soybean meal | Coast cross hay |
| 0BAN | 0 | 30 | 10 | 60 |
| 25BAN | 7.5 | 22.5 | 10 | 60 |
| 50BAN | 15 | 15 | 10 | 60 |
| 75BAN | 22.5 | 7.5 | 10 | 60 |
| Ingredients bromatological composition (g $kg^{-1}$ of dry matter) | | | | |
| Dry matter | 868.3 | 888.9 | 907.9 | 892.0 |
| Organic matter | 828.7 | 874.2 | 829.4 | 820.0 |
| Crude protein | 65.6 | 111.0 | 609.1 | 101.0 |
| Neutral detergent fiber | 324.1 | 153.9 | 154.6 | 783.0 |
| Acid detergent fiber | 127.8 | 118.5 | 88.5 | 374.0 |
| Ether extract | 72.0 | 115.0 | 43.0 | 12.8 |
| Mineral matter | 45.6 | 14.7 | 78.5 | 72.0 |
| Total digestible nutrients | 780.0 | 850.0 | 800.0 | 730.0 |
| Lignin | 79.0 | 71.5 | 47.5 | - |
| Total phenols | 6.9 | 2.5 | 1.4 | - |
| Total tannin | 3.0 | 1.3 | 0.7 | - |
| Condensed tannin | 0.8 | 0.05 | 0.01 | - |
| Diet chemical composition (g $kg^{-1}$ of dry matter) | | | | |
| | 0BAN | 25BAN | 50BN | 75BAN |
| Dry matter | 893.0 | 891.3 | 889.7 | 888.1 |
| Crude protein | 154.8 | 151.4 | 148.0 | 144.6 |
| Neutral detergent fiber | 531.4 | 544.2 | 557.0 | 569.7 |
| Acid detergent fiber | 514.2 | 514.9 | 515.6 | 516.3 |
| Ether extract | 46.5 | 43.3 | 40.0 | 36.8 |
| Mineral matter | 55.5 | 57.8 | 60.1 | 62.4 |
| Total digestible nutrients | 773.0 | 767.8 | 762.5 | 757.3 |
| Crude energy (kcal $kg^{-1}$) | 3951.95 | 3913.45 | 3874.84 | 3836.75 |

Empty body weight (FLW-GIT) and biological yield (HCW/LW*100) were calculated as well as hot carcass yield (HCW/FLW*100).

Carcass evaluation was carried out 24 h after cooling. The yield calculation as a percentage of body components was based on fasting live weight (FLW), and calculations of the percentage yield of commercial cuts was based on the whole carcass weight.

Also, the loin eye area, length, width, fat thickness and carcass composition of bone, muscle and fat, were determined in the cross section of the 12$^{th}$ and 13$^{th}$ ribs from the left half carcass in *Longissimus lumborum* muscle (Alves et al., 2014).

A 6.0 cm long, 2.0 cm wide and 1.0 cm thick strip of the *Longissimus lumborum* and *Triceps brachii* muscles was collected from each carcass immediately after slaughter and again after 24 h of cooling. These samples were fixed, cleaved dehydrated, clarified and embedded in paraffin and sectioned with a thickness of five microns. Sections were stained with *Gomori trichrome* and analyzed under optical microscope with visible light using an immersion objective. With the aid of callipers, a 100 µm of muscle fiber was measured and the sarcomere length evaluated (Sloss and Kemp, 1978), including: sarcomere length of *Triceps brachii* muscle at slaughter (T1), sarcomere length of *Triceps brachii* muscle 24 h after slaughter (T2), difference between T1 and T2 (DT), sarcomere length of *Longissimus lumborum* muscle at the time of slaughter (L1), sarcomere length of the *Longissimus lumborum* muscle 24 h after slaughter (L2) and difference between L1 and L2 (DL).

The half carcasses were weighed and divided into commercial cuts including: rib, loin, shoulder, belly, neck and leg, which were individually weighed. The kill-out of these cuts was based on division by half carcass weight.

A gas oven was preheated to 170 °C and samples of raw meat of approximately 1 cm$^3$ were weighed and placed on aluminum trays and weighed again. The samples remained in the oven until the thermocouple showed a temperature of 40 °C. At this point, the sample was turned and remained in the oven until the internal temperature of the center of the sample reached 70 °C. The trays were removed from the oven, cooled at a temperature of 7 °C for 24 h and weighed again to calculate the percentage of cooking loss (CL) by difference of weight.

The shear force was determined using the same samples used to determine cooking losses. The samples were completely cooled and stored in bags in the refrigerator for 24 h. After this procedure, three cores per sample, cut perpendicularly to the fiber at an angle of 4 °C and a diameter of 2 cm each, were used to determine the shear force (kgf$^{-1}$cm$^2$) using a texture analyzer instrument, fitted with cutting blade with 1.016 mm thickness and a load speed of about 20 cm min$^{-1}$ and load capacity of 25 kgf$^{-1}$ cm$^2$.

Meat color was assessed on the *Longissimus lumborum* with the aid of a Minolta Chroma Meter CR-300 colorimeter, which was calibrated to a standard white title and L*, a* and b* determined, where (L*) is luminosity, (a*) the redness and (b*) the yellowness. Four assessments of color were averaged for each sample.

Lipids from *Longissimus lumborum* muscle were extracted using the method described by Bligh and Dyer (1959) and Hartman and Lago (1973). The esters formed were analyzed by gas chromatograph equipped with a capillary column, fused silica (100 m long × 0.25 mm inner diameter × 0.2 mm thick film) and flame ionization detector. The column was heated to 35 °C for 2 min and was increased 10 °C per minute until reaching 150 °C, standing for 2 min, then increased by 2 °C per minute until 200 °C, remaining for 2 min and again increased by 2 °C per minute up to 220 °C, remaining at this temperature for 21 min, totaling 73.5 min. Nitrogen was used as a carrier gas at 0.9 mL min$^{-1}$. The sample volume injected (split mode) was 1 µL. The temperature used for the detector (FID) was 280 °C. The fatty acids were identified by comparison with referenced standard retention times. The retention times and areas were automatically computed by GC Solution software.

Saturated fatty acids (SFA), unsaturated fatty acid (UFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) were calculated from the percentage of fatty acids identified in the chromatograms. The following ratios were calculated: UFA/SFA, PUFA/SFA, MUFA/SFA, PUFA/MUFA, and omega 6 (ω6) to omega 3 (ω3) polyunsaturated fatty acids ratio (ω6:ω3). The desirable fatty acid proportion (DFA) was calculated according to Rhee (1992): DFA = (MUFA + PUFA + C18:0).

The nutritional quality of the lipid fraction was obtained by the atherogenity index (AI): AI = [(C12:0) + (4*C14:0) + (C16:0)] / [MUFA + ∑ω6 + ∑ω3]; and the thrombogenity index (TI): TI = (C14:0 + C16:0 + C18:0) / [(0.5*∑ω6 + (3*∑ω3) + ( ∑ω3/∑ω6), described by Ulbricht and Southgate (1991).

The ratio between hypocholesterolemic fatty acids (h) and hypercholesterolemic fatty acids (H) was determined by the equation (Santos-Silva et al., 2002): h:H = (C18:1cis9 + C18:2n6 + C20:4n 6 + C 20:5n3 + C22:6n3)/(C14:0 + C16:0).

The experimental design was completely randomized with four treatments and six replications with the animal being the experimental unit. Statistical analyses were performed using the SAS software version 9.3. Analysis of variance (PROC GLM) and regression (PROC REG) were performed. In the regression analysis, the model was: $\gamma ij = \beta 0 + \beta 1xi + \beta 2xi^2 + \beta 3xi^3 + \alpha j + \varepsilon ij$, in which $\gamma ij$ is the dependent variable measured in animal j that was subjected to the i treatment; β = regression coefficients; *xi* is the banana leftovers replacement (0, 25, 50, and 75 %; *i* = 1 to 4), $\alpha j$ the deviations from the regression and $E_j$ the error associated with the i observation.

Principal component analysis (PROC FACTOR) was performed to examine associations between the variables analyzed.

## Results

There was a negative linear effect of replacing corn bran by banana leftovers in the diet for hot and cold carcass weights ($p < 0.05$) (Table 2). However, live weight, average daily gain, dry matter intake, slaughter weight, half carcass weight, empty body weight, weight loss by cooling and hot and cold carcass yield were not influenced by the diet. The biological yield presented a negative quadratic effect of replacing corn bran with banana leftovers in the diet ($p < 0.05$) (Table 2).

Replacing corn bran with banana leftovers in the diet had a negative linear effect on leg (kg), a positive linear effect on shoulder (%), and a negative quadratic effect on loin (kg) and fat thickness (Table 3). Other commercial cuts evaluated were not influenced by the diet.

The increase in the levels of the banana leftovers in the diet increased linearly the contents of gastrointestinal tract (%) and full rumen (kg; %), but a linear negative effect was observed for thoracic viscera (kg) and lung (%) (Table 4). Head (kg), full abomasum (%), empty abomasum (kg; %) and full omasum (%) presented a positive quadratic effect while head (%), lung (kg) full reticulum (kg), empty large intestine (kg; %) presented a negative quadratic effect with the increased levels of the banana leftovers in the diet.

Replacing corn bran by banana leftovers did not affect loin eye area width (cm), bone (g) and muscle (%)

**Table 2** – Average values for performance and carcass traits of Santa Inês lambs fed with corn bran replaced by banana leftovers (*Musa* spp.) in the diet.

| Trait | Levels of replacement | | | | Mean | CV | Pr > F | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0BAN | 25BAN | 50BAN | 75BAN | | | Linear | Quadratic | Cubic |
| | % | | | | | % | | | |
| Final live weight (kg) | 32.67 | 32.67 | 33.17 | 31.83 | 32.58 | 8.91 | 0.9950 | 0.9832 | 0.9491 |
| Average daily gain ($g^{-1}$ $animal^{-1}$ day) | 70.83 | 74.44 | 72.78 | 68.89 | 71.74 | 18.74 | 0.7520 | 0.8362 | 0.9097 |
| Fasting body weight (kg) | 27.45 | 27.27 | 28.18 | 26.93 | 27.46 | 9.60 | 0.7054 | 0.5917 | 0.5349 |
| Dry matter intake ($g^{-1}$ $animal^{-1}$ day) | 766.22 | 780.03 | 793.21 | 828.21 | 791.92 | 11.92 | 0.8853 | 0.9305 | 0.8977 |
| Hot carcass weight (kg) | 12.97 | 12.72 | 12.43 | 11.30 | 12.35 | 11.34 | 0.0202[1] | 0.8420 | 0.7529 |
| Cold carcass weight (kg) | 12.75 | 12.47 | 12.17 | 11.08 | 12.12 | 11.60 | 0.0120[2] | 0.8491 | 0.7681 |
| Half carcass weight (kg) | 6.38 | 6.23 | 6.08 | 5.54 | 6.06 | 11.60 | 0.8120 | 0.8491 | 0.7681 |
| Empty body weight (kg) | 25.72 | 25.61 | 26.35 | 25.12 | 25.70 | 10.14 | 0.7228 | 0.6172 | 0.5606 |
| Hot carcass yield (%) | 48 | 47 | 44 | 42 | 45 | 10.75 | 0.9354 | 0.7644 | 0.7916 |
| Cold carcass yield (%) | 47 | 46 | 43 | 41 | 44 | 11.02 | 0.9905 | 0.7394 | 0.6332 |
| Weight loss by cooling (%) | 2 | 2 | 2 | 2 | 2 | 32.22 | 0.9905 | 0.7394 | 0.6332 |
| Biological yield (%) | 47 | 46 | 45 | 43 | 45 | 5.57 | 0.9971 | 0.0285[3] | 0.6230 |

CV = coefficient of variation; Pr > F = probability; [1]y = 12.88012-0.00000374x; [2]y = 12.63656-0.00000370x; [3]y = 46.97696-0.00071368$x^2$.

**Table 3** – Average values for carcass cuts weight and yield of Santa Inês lambs fed with corn bran replaced by banana leftovers (*Musa* spp.) in the diet.

| Trait | Levels of replacement | | | | Mean | CV | Pr > F | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0BAN | 25BAN | 50BAN | 75BAN | | | Linear | Quadratic | Cubic |
| | % | | | | | % | | | |
| Leg (kg) | 2.160 | 2.149 | 2.065 | 1.930 | 2.076 | 11.73 | 0.0370[1] | 0.8942 | 0.9661 |
| Leg (%) | 34 | 34 | 34 | 35 | 34 | 3.91 | 0.3123 | 0.3203 | 0.3101 |
| Leg Length (cm) | 52.67 | 52.17 | 48.42 | 52.83 | 51.52 | 12.82 | 0.6388 | 0.4319 | 0.3550 |
| Leg Perimeter (cm) | 35.08 | 33.50 | 34.50 | 33.33 | 34.1 | 5.72 | 0.1599 | 0.1895 | 0.1971 |
| Loin (kg) | 0.774 | 0.744 | 0.717 | 0.628 | 0.716 | 17.44 | 0.7927 | 0.0491[2] | 0.7807 |
| Loin (%) | 12 | 12 | 12 | 11 | 12 | 11.81 | 0.9767 | 0.9631 | 0.9844 |
| Shoulder (kg) | 1.188 | 1.184 | 1.190 | 1.090 | 1.163 | 10.5 | 0.8053 | 0.1018 | 0.6090 |
| Shoulder (%) | 19 | 19 | 20 | 20 | 19 | 2.49 | 0.0436[3] | 0.4639 | 0.4128 |
| Rib (kg) | 1.838 | 1.715 | 1.675 | 1.629 | 1.714 | 16.43 | 0.6637 | 0.8272 | 0.8641 |
| Rib (%) | 29 | 27 | 28 | 30 | 28 | 14.02 | 0.8006 | 0.9719 | 0.9051 |
| Neck (kg) | 0.900 | 0.869 | 0.835 | 0.793 | 0.849 | 12.5 | 088[4] | 0.8503 | 0.9729 |
| Neck (%) | 14 | 14 | 14 | 14 | 14 | 7.06 | 0.8423 | 0.6702 | 0.5794 |
| Belly (kg) | 0.223 | 0.208 | 0.220 | 0.190 | 0.21 | 19.54 | 0.4263 | 0.3985 | 0.3572 |
| Belly (%) | 4 | 3 | 4 | 3 | 3 | 12.63 | 0.2570 | 0.2197 | 0.2147 |
| Carcass Length (cm) | 59.83 | 58.50 | 57.50 | 57.25 | 58.27 | 3.83 | 0.0767 | 0.1244 | 0.1512 |
| Fat Thickness (mm) | 3.08 | 3 | 2.99 | 2.79 | 2.97 | 9.72 | 0.5902 | 074[5] | 0.5542 |

CV = coefficient of variation; Pr > F = probability; [1]y = 2.16845-0004205x; [2]y = 0.7702-0002471$x^2$; [3]y = 18.70095+0.01437x; [4]y = 0.90258-0141$x^2$; [5]y = 3.06786 -0004626$x^2$.

**Table 4** –Average values for non-carcass components of Santa Inês lambs fed with corn bran replaced by banana leftovers (*Musa* spp.) in the diet.

| Trait | Levels of replacement | | | | Mean | CV | Pr > F | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0BAN | 25BAN | 50BAN | 75BAN | | | Linear | Quadratic | Cubic |
| | % | | | | | % | | | |
| Contents of gastrointestinal tract (kg) | 5.244 | 5.133 | 5.701 | 5.492 | 5.393 | 22.55 | 0.7625 | 0.6379 | 0.6170 |
| Contents of gastrointestinal tract (%) | 20 | 21 | 22 | 23 | 22 | 11.3 | 0.0323[1] | 0.9827 | 0.9972 |
| Abdominal viscera (kg) | 8.116 | 8.300 | 8.516 | 8.533 | 8.366 | 10.87 | 0.9509 | 0.9167 | 0.8897 |
| Abdominal viscera (%) | 25 | 25 | 26 | 27 | 26 | 9.25 | 0.7412 | 0.7977 | 0.7677 |
| Thoracic viscera (kg) | 1.516 | 1.383 | 1.416 | 1.366 | 1.42 | 8.6 | 0.0325[2] | 0.2322 | 0.2755 |
| Thoracic viscera (%) | 5 | 4 | 4 | 4 | 4 | 10.07 | 0.2325 | 0.4200 | 0.5210 |
| Head (kg) | 1.600 | 1.550 | 1.433 | 1.483 | 1.516 | 7.75 | 0.6844 | 0.0498[3] | 0.4238 |
| Head (%) | 5 | 5 | 4 | 5 | 5 | 8.31 | 0.6641 | 0.0222[4] | 0.1737 |
| Liver (kg) | 0.283 | 0.300 | 0.300 | 0.316 | 0.3 | 14.27 | 0.5962 | 0.6777 | 0.6744 |
| Liver (%) | 0.90 | 0.90 | 0.90 | 1 | 0.90 | 17.66 | 0.6814 | 0.6798 | 0.6397 |
| Heart (kg) | 0.100 | 0.100 | 0.116 | 0.100 | 0.104 | 19.6 | 0.4434 | 0.2520 | 0.1947 |
| Heart (%) | 0.30 | 0.30 | 0.40 | 0.30 | 0.30 | 24.7 | 0.5480 | 0.3752 | 0.3322 |
| Lung (kg) | 0.400 | 0.433 | 0.350 | 0.333 | 0.379 | 22.2 | 0.2602 | 0.0127[5] | 0.2468 |
| Lung (%) | 1 | 1 | 1 | 1 | 1 | 20.46 | 059[6] | 0.1553 | 0.1768 |
| Kidneys (kg) | 0.073 | 0.075 | 0.071 | 0.084 | 0.076 | 22.66 | 0.6850 | 0.5942 | 0.5154 |
| Kidneys (%) | 0.20 | 0.20 | 0.20 | 0.30 | 0.20 | 19.61 | 0.5851 | 0.4505 | 0.3563 |
| Full Rumen (kg) | 3.882 | 4.365 | 4.387 | 4.645 | 4.32 | 17.56 | 0.0361[7] | 0.5833 | 0.6209 |
| Full rumen (%) | 12 | 13 | 13 | 15 | 13 | 16.09 | 0.0382[8] | 0.4752 | 0.4758 |
| Empty rumen (kg) | 0.501 | 0.558 | 0.524 | 0.540 | 0.531 | 10.28 | 0.0878 | 0.1555 | 0.2314 |
| Empty rumen (%) | 2 | 2 | 2 | 2 | 2 | 9.5 | 0.0555 | 0.0688 | 0.0748 |
| Full abomasum (kg) | 0.319 | 0.356 | 0.337 | 0.390 | 0.351 | 22.95 | 0.4060 | 0.4243 | 0.4036 |
| Full abomasum (%) | 1 | 1 | 1 | 1 | 1 | 21.5 | 0.2859 | 0.0250[9] | 0.2540 |
| Empty abomasum (kg) | 0.19 | 0.20 | 0.20 | 0.22 | 0.20 | 17.67 | 0.6065 | 0.0461[10] | 0.6060 |
| Empty abomasum (%) | 0.60 | 0.60 | 0.60 | 0.70 | 0.60 | 13.06 | 0.2468 | 0.0152[11] | 0.1612 |
| Full omasum (kg) | 0.195 | 0.174 | 0.215 | 0.209 | 0.198 | 18.54 | 0.1384 | 0.1046 | 0.1148 |
| Full omasum (%) | 0.60 | 0.50 | 0.60 | 0.60 | 0.60 | 14.88 | 0.1018 | 081[12] | 0.1124 |
| Empty omasum (kg) | 0.110 | 0.080 | 0.115 | 0.093 | 0.099 | 29.09 | 0.0523 | 0.0596 | 0.0516 |
| Empty omasum (%) | 0.30 | 0.20 | 0.30 | 0.30 | 0.30 | 22 | 0.0504 | 0.0502 | 0.0520 |
| Full reticulum (kg) | 0.178 | 0.160 | 0.250 | 0.149 | 0.184 | 49.66 | 0.2449 | 0.0244[13] | 0.0893 |
| Full reticulum (%) | 0.50 | 0.50 | 0.80 | 0.50 | 0.60 | 52.51 | 0.2902 | 0.1543 | 0.1145 |
| Empty reticulum (kg) | 0.103 | 0.098 | 0.102 | 0.085 | 0.097 | 21.79 | 0.6626 | 0.5463 | 0.5489 |
| Empty reticulum (%) | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 20.59 | 0.6092 | 0.5952 | 0.5414 |
| Full large intestine (kg) | 1.183 | 1.062 | 1.284 | 1.148 | 1.169 | 18.67 | 0.1402 | 0.1001 | 0.0944 |
| Full large intestine (%) | 4 | 3 | 4 | 4 | 4 | 16.71 | 0.1139 | 0.0851 | 0.0861 |
| Empty large intestine (kg) | 0.294 | 0.288 | 0.279 | 0.248 | 0.277 | 16.48 | 0.7550 | 0.0412[14] | 0.7171 |
| Empty large intestine (%) | 0.90 | 0.90 | 0.80 | 0.80 | 0.80 | 14.86 | 0.9456 | 040[15] | 0.9722 |
| Full small intestine (kg) | 0.803 | 0.746 | 0.800 | 0.827 | 0.794 | 16.42 | 0.4479 | 0.4982 | 0.5678 |
| Full small intestine (%) | 2 | 2 | 2 | 3 | 2 | 14.01 | 0.5162 | 0.6304 | 0.7601 |
| Empty small intestine (kg) | 0.535 | 0.518 | 0.519 | 0.533 | 0.526 | 11.99 | 0.7759 | 0.8944 | 0.9656 |
| Empty small intestine (%) | 2 | 2 | 2 | 2 | 2 | 15.50 | 0.9341 | 0.9356 | 0.8473 |

CV = coefficient of variation; Pr > F = probability; [1]$y = 20.06987+0.0402x$; [2]$y = 1.4833-0167x$; [3]$y = 1.5667+0133x^2$; [4]$y = 4.86165-0503x^2$; [5]$y = 0.41310-0001551x^2$; [6]$y = 1.25842-0004335x$; [7]$y = 3.97333+0925x$; [8]$y = 12.11347+0.03129x$; [9]$y = 0.99846+000367x^2$; [10]$y = 0.190125+0000562x^2$; [11]$y = 0.57573+0002013x^2$; [12]$y = 0.57348+0001643x^2$; [13]$y = 0.19000-0000257x^2$; [14]$y = 0.29044-0002867x^2$; [15]$y = 0.89838-0002088x^2$.

(Table 5). However, loin eye area ($cm^2$), loin eye area length (cm) and muscle (g) presented a negative quadratic response, and loin eye area fat thickness (cm), initial sample weight 12$^{th}$ rib (g) and fat (g; %) presented a negative linear effect when increased levels of the banana leftovers were included in the diet.

The sarcomere length of *Longissimus lumborum* muscle at the time of slaughter (L1) and yellowness (b*) presented a positive quadratic effect while cooking loss and redness (a*) presented a negative quadratic effect with the increased levels of the banana leftovers in the diet (Table 5).

The first two components explained 67 % of the variance between all traits evaluated (Figure 1). The first autovector (46 %) showed that increasing the levels of corn bran replaced by banana leftovers in diet of lambs increased hot and cold carcass weight and yield, eye muscle area, eye muscle area length, width and fat thick-

**Table 5** – Average values for loin eye area, carcass composition and meat traits of Santa Inês lambs fed with corn bran replaced by banana leftovers (*Musa* spp.) in the diet.

| Trait | Levels of replacement | | | | Mean | CV | Pr > F | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0BAN | 25BAN | 50BAN | 75BAN | | | Linear | Quadratic | Cubic |
| | % | | | | | % | | | |
| Eye muscle area ($cm^2$) | 9.89 | 10.31 | 10.69 | 8.52 | 9.85 | 17.38 | 0.8857 | 0.0112[1] | 0.4344 |
| Eye muscle area length (cm) | 5.28 | 5.25 | 5.17 | 4.97 | 5.17 | 8.09 | 0.9632 | 0.0486[2] | 0.9312 |
| Eye muscle area width (cm) | 2.58 | 2.62 | 2.62 | 2.45 | 2.57 | 11.88 | 0.9908 | 0.9069 | 0.8132 |
| Eye muscle area fat thickness (cm) | 0.15 | 0.13 | 0.10 | 0.10 | 0.12 | 31.15 | 0.0488[3] | 0.5296 | 0.4753 |
| Initial sample weight 12th 13th rib (g) | 98.66 | 100.25 | 79.14 | 75.96 | 88.5 | 24.05 | 0.0366[4] | 0.2956 | 0.3085 |
| Bone (g) | 24.10 | 29.74 | 21.92 | 24.21 | 24.99 | 30.88 | 0.1100 | 0.0987 | 0.1102 |
| Muscle (g) | 49.68 | 53 | 43.08 | 41.66 | 46.86 | 22.71 | 0.3143 | 0.0488[5] | 0.2762 |
| Fat (g) | 21.36 | 18.17 | 13.07 | 11.05 | 15.92 | 44.88 | 0.0415[6] | 0.7291 | 0.7043 |
| Bone (%) | 25 | 30 | 28 | 32 | 29 | 23.12 | 0.0219[7] | 0.2800 | 0.2824 |
| Muscle (%) | 51 | 54 | 55 | 55 | 54 | 13.27 | 0.7744 | 0.9419 | 0.9912 |
| Fat (%) | 22 | 18 | 16 | 15 | 17 | 32.64 | 0.0499[8] | 0.7428 | 0.7969 |
| T1 (units$^{-1}$100 µm) | 49.50 | 51.17 | 49.17 | 51 | 50.21 | 6.68 | 0.2671 | 0.2434 | 0.2351 |
| T2 (units$^{-1}$100 µm) | 42.33 | 44.17 | 43.33 | 45.33 | 43.79 | 7.92 | 0.3686 | 0.4054 | 0.3956 |
| DT | 7.17 | 7 | 5.83 | 5.66 | 6.42 | 28.95 | 0.7347 | 0.5662 | 0.5620 |
| L1 (units$^{-1}$100 µm) | 44.16 | 38.50 | 38 | 42.83 | 40.88 | 6.55 | 0.0647 | 0.0474[9] | 0.9731 |
| L2 (units$^{-1}$100 µm) | 36.33 | 34.16 | 32.83 | 35.16 | 34.63 | 6.26 | 0.6343 | 0.7422 | 0.4820 |
| DL | 7.83 | 7.66 | 5.16 | 4.33 | 6.25 | 37.58 | 0.0900 | 0.2946 | 0.5411 |
| Shear force ($kgf^{-1}$ $cm^2$) | 2.52 | 3.22 | 3.01 | 2.66 | 2.86 | 15.89 | 0.0597 | 0.1913 | 0.3556 |
| Cooking loss (g) | 6.01 | 5.73 | 4.91 | 4.58 | 5.31 | 11.95 | 0.7493 | 083[10] | 0.3908 |
| a* | 2.07 | 4.86 | 2.55 | 2.03 | 2.88 | 49.01 | 025 | 061[11] | 0.5147 |
| b* | 5.64 | 3.05 | 6.13 | 4.74 | 4.89 | 32.49 | 021 | 018[12] | 0.5023 |
| L* | 32.58 | 29.92 | 31.87 | 34.46 | 32.22 | 13.18 | 0.3627 | 0.4819 | 0.6226 |

CV = coefficient of variation; Pr > F = probability; T1 = sarcomere length of Triceps brachii muscle at the time of slaughter; T2 = sarcomere length of Triceps brachii muscle 24 h after slaughter; DT = difference between T1 and T2; L1 = sarcomere length of Longissimus lumborum muscle at the time of slaughter; L2 = sarcomere length of the Longissimus lumborum muscle 24 h after slaughter and DL = difference between L1 and L2; a* = red level; b* = yellow content; L* = luminosity. [1]y = 10.43845-0026786$x^2$; [2]y = 5.28929-0005605$x^2$; [3]y = 0.14833-0073333x; [4]y = 101.88317-0.35684x; [5]y = 50.83393-0182$x^2$; [6]y = 21.3185-0.14409x; [7]y = 25.3835+0.08501x; [8]y = 20.77733-0.08451x; [9]y = 44.177+042$x^2$; [10]y= 6.0675-002$x^2$; [11]y = 2.4141-013$x^2$; [12]y = 5.1392+004$x^2$

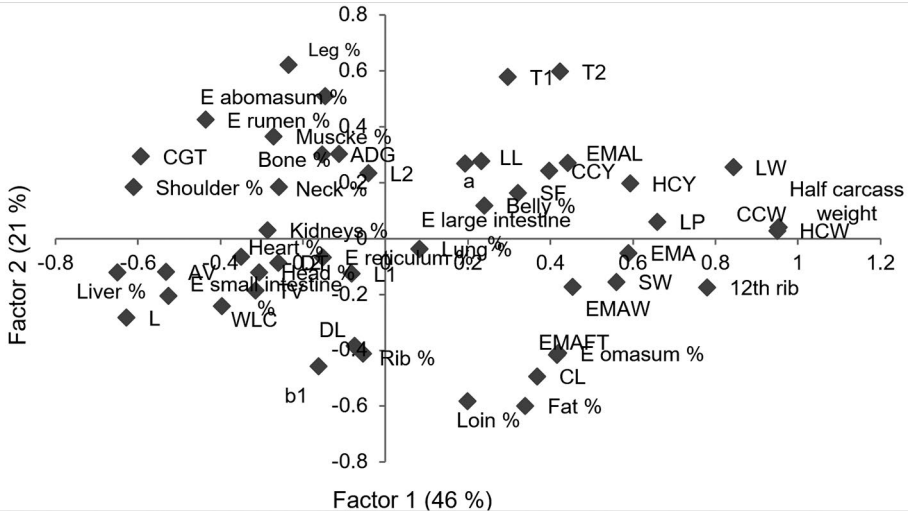


**Figure 1** – Principal component analysis for performance, carcass and non-carcass traits of Santa Inês lambs fed with corn bran replaced by banana leftovers (*Musa* spp.) in the diet. LW = live weight; AGD = average daily gain; SW = slaughter weight; HCW = hot carcass weight; CCW = cold carcass weight; HCY = hot carcass yield; CCY = cold carcass yield; WLC = weight loss by cooling; LL = leg length; LP = leg perimeter; AV = Abdominal viscera; TV = thoracic viscera; E rumen % = empty rumen (%); E abomasum % = empty abomasum (%); E omasum % = empty omasum (%); E reticulum % = empty reticulum (%); E large intestine % = empty large intestine (%); E small intestine (%) = empty small intestine (%); CGT = content of gastrointestinal tract; EMA = eye muscle area; EMAL = eye muscle area length; EMAW = eye muscle area width; EMAFT = eye muscle area fat thickness; 12th rib = initial sample weight 12th rib; SF = shear force; CL = cooking loss.

ness, live and slaughter weight and decreased the bone percentage and the content of gastrointestinal tract. The second autovector (21 %) showed that with an increase in live weight, hot and cold carcass weight and yield, live weight and eye muscle area length, a reduction in slaughter weight and carcass length was observed.

Replacing corn brain with banana leftovers in the diet had no effect on fatty acid profile and values of DFA, ω3, 6 and 9, ω6:ω3, UFA:SFA, PUFA:SFA, MUFA:SFA, PUFA:MUFA, AI, TI and h:H of *Longissimus lumborum* muscle of Santa Inês lambs (Table 6).

In the meat lipid profile of the Santa Inês lambs studied, sixteen fatty acids were identified, seven saturated fatty acids (SFA), four monounsaturated fatty acids (MUFA) and five polyunsaturated fatty acids (PUFA). The fatty acids with highest concentrations included stearic (C160, 79.98 g 100 $g^{-1}$), linoleic (C18:2n9c, 8.45 g 100 $g^{-1}$), homo-linolenic (C20:3n6, 3.25 g 100 $g^{-1}$) and palmitic acid (C16:0, 2.03 g 100 $g^{-1}$) (Table 6). Saturated fatty acid ranged from 84.41 to 85.91 g 100 $g^{-1}$ among treatments. MUFA, PUFA and DFA averaged 2.93 g 100 $g^{-1}$, 12.34 g 100 $g^{-1}$ and 95.24 g 100 $g^{-1}$ respectively. UFA:SFA, PUFA:SFA and MUFA:SFA ratio averaged 0.18, 0.15 and 0.03, respectively. The average of AI, TI and h:H were 0.97, 32.80, and 1.23, respectively (Table 6).

## Discussion

The use of alternative sources of energy in sheep nutrition is important to the provision of a suitable des-

**Table 6** – Average values for fatty acid profile and quality indices (g 100 $g^{-1}$ of the total fatty acids) in *Longissimus lumborum* muscle of Santa Inês lambs fed with corn bran replaced by banana leftovers (*Musa* spp.) in the diet.

| Fatty acid profile | Levels of replacement | | | | Mean | CV | Pr > F | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0BAN | 25BAN | 50BAN | 75BAN | | | Linear | Quadratic | Cubic |
| | % | | | | | % | | | |
| SFA | 85.91 | 84.41 | 84.59 | 84.97 | 84.97 | 2.56 | 0.554 | 0.315 | 0.718 |
| C 14:0 | 0.66 | 1.84 | 0.91 | 0 | 0.89 | 230.06 | 0.542 | 0.940 | 0.167 |
| C 15:0 | 0.45 | 0.64 | 0.26 | 0.41 | 0.44 | 95.19 | 0.546 | 0.936 | 0.166 |
| C 16:0 | 1.91 | 2.46 | 1.56 | 2.22 | 2.03 | 73.19 | 0.981 | 0.930 | 0.282 |
| C 17:0 | 1.41 | 1.48 | 1.78 | 1.28 | 1.50 | 28.01 | 0.882 | 0.121 | 0.200 |
| C 18:0 | 81.47 | 77.78 | 79.90 | 80.93 | 79.98 | 4.29 | 0.940 | 0.118 | 0.286 |
| C 20:0 | 0 | 0.10 | 0 | 0.13 | 0.05 | 337.11 | 0.437 | 0.877 | 0.211 |
| C 24:0 | 0 | 0.11 | 0.17 | 0 | 0.07 | 271.32 | 0.868 | 0.108 | 0.606 |
| UFA | 14.53 | 16.29 | 15.12 | 15.06 | 15.26 | 14.93 | 0.923 | 0.353 | 0.347 |
| MUFA | 2.88 | 3.57 | 2.68 | 2.51 | 2.93 | 48.30 | 0.470 | 0.480 | 0.384 |
| C 14:1 | 0.45 | 0.64 | 0.26 | 0.41 | 0.44 | 95.26 | 0.328 | 0.413 | 0.461 |
| C 16:1 | 0.58 | 0.77 | 0.50 | 0.39 | 0.57 | 77.80 | 0.328 | 0.413 | 0.461 |
| C 18:1n9c C18:1n9t | 1.77 | 1.81 | 1.92 | 1.71 | 1.80 | 81.17 | 0.985 | 0.846 | 0.887 |
| C 20:1n9 | 0.08 | 0.35 | 0 | 0 | 0.11 | 196.99 | 0.178 | 0.159 | 0.027 |
| PUFA | 11.66 | 12.72 | 12.45 | 12.55 | 12.34 | 18.21 | 0.580 | 0.614 | 0.682 |
| C 18:2n9c | 8.01 | 8.58 | 8.32 | 9 | 8.45 | 17.53 | 0.344 | 0.929 | 0.525 |
| C 18:3n6 | 0.08 | 0.10 | 0.09 | 0.28 | 0.13 | 201.44 | 0.242 | 0.458 | 0.606 |
| C 18:3n3 | 0.50 | 0.43 | 0.39 | 0.19 | 0.39 | 106.12 | 0.221 | 0.723 | 0.805 |
| C 20:2 | 0.08 | 0.35 | 0 | 0 | 0.11 | 196.99 | 0.178 | 0.159 | 0.027 |
| C 20:3n6 | 2.99 | 3.26 | 3.65 | 3.07 | 3.25 | 37.11 | 0.782 | 0.413 | 0.627 |
| Fatty acid quality indices | | | | | | | | | |
| DFA | 96 | 94.07 | 95.02 | 95.99 | 95.24 | 2.50 | 0.840 | 0.163 | 0.517 |
| ω3 | 0.50 | 0.43 | 0.39 | 0.19 | 0.38 | 106.12 | 0.221 | 0.723 | 0.805 |
| ω6 | 3.07 | 3.36 | 3.74 | 3.36 | 3.38 | 35.97 | 0.596 | 0.513 | 0.710 |
| ω9 | 9.86 | 10.74 | 10.24 | 10.72 | 10.37 | 18.21 | 0.568 | 0.802 | 0.504 |
| ω6:ω3 | 3.96 | 5.88 | 4.62 | 3.48 | 4.72 | 47.14 | 0.734 | 0.341 | 0.577 |
| UFA:SFA | 0.17 | 0.19 | 0.18 | 0.18 | 0.18 | 17.57 | 0.856 | 0.333 | 0.395 |
| PUFA:SFA | 0.14 | 0.15 | 0.15 | 0.15 | 0.15 | 20.71 | 0.565 | 0.545 | 0.697 |
| MUFA:SFA | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 48.54 | 0.487 | 0.453 | 0.363 |
| PUFA:MUFA | 4.81 | 4.19 | 9.22 | 6.35 | 6.13 | 85.12 | 0.345 | 0.612 | 0.173 |
| AI | 0.66 | 1.98 | 0.76 | 0.40 | 0.97 | 183.48 | 0.560 | 0.277 | 0.313 |
| TI | 29.19 | 36.63 | 32.13 | 33.48 | 32.80 | 60.60 | 0.837 | 0.728 | 0.634 |
| h:H | 1.30 | 1.18 | 1.27 | 1.16 | 1.23 | 126.13 | 0.910 | 0.993 | 0.891 |

Pr > F = probability; SFA = saturated fatty acids; UFA = unsatured fatty acids; MUFA = monounsaturated fatty acid; PUFA = polyunsaturated fatty acid; DFA = desirable fatty acids; ω3 = omega 3 polyunsaturated fatty acids; ω6 = omega 6 polyunsaturated fatty acids; ω9 = omega 9 polyunsaturated fatty acids; ω6:ω3 = omega 6 to omega 3 polyunsaturated fatty acids ratio; AI = atherogenity index; TI = thrombogenity index; h:H = hypocholesterolemic fatty acids to hypercholesterolemic fatty acids ratio.

tination for byproducts of agricultural production and a reduction in animal production costs. Average daily gain (71.74 g animal$^{-1}$ day) observed in this study was lower than those predefined in NRC (2007) for a daily weight gain of 100 g, due to the high neutral detergent fiber level of the banana leftovers compared to the corn bran (Table 1).

As dry matter intake (791.92 g$^{-1}$ animal$^{-1}$ day) was not affected by the diet, the animals had similar final (32.58 kg) and fasting (27.46 kg) weights. However, the weights of hot and cold carcass presented a negative linear effect with increased banana leftovers included in the diet. This can be explained by increases in neutral detergent fiber content that interfered in energy available and synchronization of protein use by rumen microorganisms in the diet as increases in the level of banana leftovers (less starch than corn) led to lower weights of hot and cold carcass related to the retention time of the diets, evidenced by the greater content of gastrointestinal tract (%), mainly the full rumen (%).

The general average hot carcass (45 %) and cold carcass yields (44 %) can be considered a good result for the Santa Inês breed because, in general, purebred Santa Inês showed lower growth performance than crossbred animals reflecting directly in the hot and cold carcass yields (Cardoso et al., 2013). These values related to the production of carcass per unit of body weight and may vary greatly in sheep (40-60 %) in terms of a set of intrinsic factors such as genotype, age, sex, type of birth, degree of fat and weight, as well as extrinsic factors such as number of hours fasting, breeding system, feeding system, cooling conditions and stress (Osório and Osório, 2003).

The weight loss by cooling (2 %) was not affected by the diet and was similar to those observed by other authors working with alternative foods for sheep (Menezes et al., 2013). Overall, subcutaneous fat deposition (average of 2.97 mm) did not differ in lambs fed different dietary treatments. Previous research (Andrade et al., 2017) has shown that fat thickness around 3 mm provides better protection against moisture loss during carcass chilling when compared to 2 mm. The percentage of weight loss by cooling depends on factors such as pH, loss of moisture and chemical reactions that occur in the muscle. Change in weight loss by cooling of the muscle has been shown to be closely related to pH, and a sensitive indicator of variations in the charges and structure of muscle proteins (Bouton et al., 1971). Thus, the lower this percentage, the greater the likelihood of the carcass being handled and stored properly.

The similarity of rib and belly weights, as well as yields among the treatments was due to the proportionality of growth with higher weight of cuts occurring with increasing body mass. Carcasses with different weights give cuts of varying weights, but variation of carcass weight does not always imply cut weight variation which may be associated with possible differences in growth of tissues, especially muscle and fat.

The inclusion of banana leftovers linearly reduced the weight of the leg which is an important commercial cut. Tissue composition of carcass improves qualitative aspects of meat products and facilitates commercialization since carcasses with poor muscle development have lower market acceptability (Pinheiro and Jorge, 2010).

The differences for non-carcass components of Santa Inês lambs fed with corn bran replaced by banana leftovers, such as contents of the gastrointestinal tract (%), thoracic viscera (kg), lung (%) and full rumen (%) had economic importance since they influenced the hot and cold carcass weights. The increase in the gastrointestinal tract may be related with the retention time of the diets due to the high neutral detergent fiber content. Thus, the quantification of the non-carcass constituent organs and body measurements can reduce economic loss and provide the correct valuation of diets and animals for meat production (Morais et al., 2014).

The inclusion of banana leftovers in the lamb diet decreases eye muscle area fat thickness (cm) and fat proportion (%). This can be explained by the reduction in the protein/energy available in the diet with increasing levels of banana leftovers that was determinant for the lower fat deposition in the carcass. According to Landim et al. (2015), the Santa Inês breed has a lower body fat percentage and higher muscle:fat ratio, providing meat with less fat as compared to wool breeds. High proportions of adipose tissue in sheep cuts may reduce consumption and price, as this may be associated with health risks (Pinheiro and Jorge, 2010).

Diet (Menezes et al., 2016) contributed to the positive quadratic effect found in sarcomere length of *Longissimus lumborum* muscle (L1), which did not happen with *Triceps brachii*. Additionally, the sarcomere length, the amount of connective tissue and proteolysis of myofibrillar proteins can explain the variation among the different muscles analyzed (Koohmaraie et al., 2002).

The influence of feeding on meat tenderness is associated with subcutaneous fat thickness and intramuscular fat content, as well as breed, gender and the finishing system (Hopkins and Mortimer, 2014; Baldassini et al., 2017). In this study, the shear force ranged from 2.52 to 3.22 kgf$^{-1}$cm$^2$ and was not influenced by diet. The cooking loss is directly related to the amount of fat and water retention capacity. In this study, the cooling loss was influenced by the diet and was associated with the eye muscle area fat thickness and carcass fat (g; %) that exhibited the same negative linear behavior.

Color is the fresh meat quality attribute that most influences choice by the consumer (Gracia and De-Magistris, 2013). Dawson et al. (2002) found that red intensity increased with slaughter weight in sheep. Pinheiro et al. (2009) described that the lean color was influenced by the brightness and intensity of red, while the intensity of the yellow color was the most significant for fat. The average value found in this study for yellowness (4.89) and luminosity (32.22) was considered attractive

to the consumer and normal for sheep meat (b*: 3.34 to 5.65 and L*: 31.36 to 38.0), while the redness (2.88) was below the values considered ideal for sheep (a*: 12.27 to 18.01), indicating darker meat as the color of preference (Bressan et al., 2001). This may be a consequence of the increase in myoglobin oxidation during the storage period (Šuput et al., 2013).

To better explain the (co) variances between performance, carcass and non-carcass components, a principal components analysis was performed. It was observed that animals which had a higher final body weight tended to record higher weights for the commercial cuts (leg, shoulder, neck, belly), as expected. This result agrees with Menezes et al. (2013) who demonstrated that carcass yield increased with body weight. However, the development of organs showed different growth stages, as each animal reached maturity at different physiological ages (Carvalho et al., 2016).

The diet has an intrinsic relationship with fatty acid profile in meat, and directly affects its nutritional and sensory values as well as shelf life (Guerrero et al., 2013). In the present study, replacing corn bran with banana leftovers did not affect the fatty acid profile of *Longissimus lumborum* muscle of Santa Inês lambs, indicating that levels up to 75 % of this feedstuff may be used in the diet without compromising nutritional values.

The levels of SFA observed in this study were greater than those found by Madruga et al. (2008), in sheep. These authors reported SFA values between 75 % and 79 %, and average stearic acid (18:0), palmitic acid (16:0) and myristic acid (14:0) values of 37 %, 20 % and 1 %, respectively.

The MUFA and PUFA values were lower than reported by Madruga et al. (2008) and Costa et al. (2015). Different feeding systems may produce varied concentrations of UFA in meat due to higher levels of certain UFA or because the differences in the way the food was fermented in the rumen (Wood et al., 2008).

Values of desirable fatty acids (DFA) in the lamb meat reported by Madruga et al. (2008), Coutinho et al. (2014) and Costa et al. (2015) ranged from 67 % to 84 % and were lower than the value observed in the present study (95 %). The DFA, which has been suggested as an indicator of dietary risk for cardiovascular disease, was useful when assessing meat quality (Costa et al., 2015). The ω6/ω3 ratio from the present study is in line with that recommended (4:1) by the World Health Organization (2003) and may be beneficial in human diets.

The lamb meat of the different treatments showed low values of UFA:SFA, characterized by a lower concentration of UFA. Coutinho et al. (2014) obtained higher values of UFA:SFA (1.01) due to a higher percentage of UFA in the different meat cuts. The average of PUFA:SFA was less than the minimum value (0.4) recommended value by the World Health Organization (2003). Costa et al. (2015) also reported lower PUFA:SFA ratios. The values of MUFA:SFA were low. Those results were undesirable from the point of nutritional quality. Coutinho et al. (2014) commented that low levels in the lipid profile from animals fed with different levels of energy resources may result from ruminal biohydrogenation and the lack of difference in the deposition of intramuscular fat between treatments.

The atherogenity and thrombogenity indices were frequently used to access the nutritional value and consumer health of meat. The acceptable value for human health for both indices were less than 1.0 (Sinanoglou et al., 2013). Ulbricht and Southgate (1991) suggest that AI and TI were more suitable measures of the atherogenicity of foods than the polyunsaturated/saturated fatty acid ratio. In the present study, the average AI was 0.97, which is close to 1.0, an acceptable level for human health. However, the average TI (32.80) was higher than that accepted for human health. This index is defined by the relationship between the saturated and unsaturated fatty acids. The values of TI observed were due to a high level of stearic acid (79.98) that had a neutral effect on cholesterol on LDL and high-density lipoprotein (HDL) cholesterol as described above. Therefore, these high levels may not have a significant practical effect on human health.

The average of h:H of different groups was higher than that observed by Cruz et al. (2011). The h:H index may be useful when assessing the cholesterolemic effect of lipids, where higher values mean a low probability of cardiovascular diseases.

## Conclusions

Replacement of up to 75 % of the corn bran with banana leftovers in the diet did not interfere with the intake, performance, meat traits and fatty acid profile of Santa Inês lambs.

The use of fruit byproducts can be included in the ruminant diet, although the decision as to use should be based on the cost, logistics and available quantity of these byproducts.

## Authors' Contributions

Conceptualization: Menezes, A.M.; McManus, C.; Souza, J.R.; Louvandini, H. Data acquisition: Menezes, A.M.; Esteves, G.I.F.; Kendlein, L.; Souza, J.R. Data analysis: McManus, C.; Louvandini, H.; Peripolli, V. Design of Methodology: Menezes, A.M.; Louvandini, H.; McManus, C. Writing and editing: Menezes, A.M.; Tanure, C.B.G.S.; Peripolli, V.; McManus, C.; Louvandini, H.

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