

Physical-Chemical Composition, Fatty Acid Profile and Sensory Attributes of Meat of Lambs Fed With Saccharine Sorghum Silage

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Abstract

The objective of this work was to evaluate the qualitative and sensory characteristics and the fatty acid profiles of the meat of lambs fed with silages of two saccharine sorghum varieties and compare them with forage sorghum and maize silages. Twenty non-castrated male Suffolk lambs were arranged in a completely randomised block design, and the treatments consisted of the following silages: forage sorghum (FORSOR), saccharine sorghum ('BRS506'), saccharine sorghum ('BRS511') and maize (MAIZE). The animals were slaughtered after 70 days in the feedlot. The carcasses were cooled at 4 °C for 24 h. The *longissimus thoracis et lumborum* muscle was removed for analysis. No differences ($p > 0.05$) between treatments were found for chemical composition and qualitative and sensory characteristics of the evaluated meat. Lambs fed with 'BRS506' presented muscles with higher total unsaturated and monounsaturated fatty acids and with higher percentages of oleic acid. The BRS506 saccharin sorghum silage increased the meat total unsaturated and monounsaturated fatty acid contents, which are beneficial to human health; thus, this silage can replace maize silage in the feed for finishing lambs.

Keywords: BRS506, feedlot, meat quality, roughage

1. Introduction

Saccharine sorghum (*Sorghum bicolor* (L.) Moench) was improved to be used in ethanol production, mainly during the sugarcane off-season (De Nóbile & Nunes, 2014), because it is a bioenergetic species whose culm is rich in fermentable sugars (Anandan, Zoltan, Khan, Ravi, & Blümmel, 2012; Orrico Junior et al., 2015). In addition, this species resembles sugarcane plants due to a rapid productive cycle, mechanisable harvest, succulent culms and good bagasse production (Parrella, 2011), which can be used for bioenergy production and as animal feed (De Nóbile & Nunes, 2014).

Sorghum silage has been used for finishing animals in feedlots because it has high dry matter production and is less sensitive to short drought periods; thus, studies are needed for the development of hybrids more adapted, easily cultivated and ensiled (Neumann et al., 2002; Vaz et al., 2005).

The diet of lambs can modify their carcass conformation and meat physical-chemical and organoleptic properties, such as fatty acid profile, softness and colour (Franco, Crecente, Vázquez, Gómez, & Lorenzo, 2013). The silage offered to animals can affect the quality of their final products, such as milk and meat (Campos et al., 2017; Milewski et al., 2014), denoting the importance of studies that investigate the diet effects (Holanda Júnior, 2006; Manarelli et al., 2019; Pereira et al., 2016). Considering that other studies (Manarelli et al., 2019; Orrico Junior et al., 2015) found variations in the effect of ‘BRS506’ saccharine sorghum silage on animal performance and carcass characteristics, it is important to evaluate the quality parameters of meat of sheep fed with this silage.

Thus, the objective of the present study was to evaluate the chemical, qualitative and sensory characteristics as well as the fatty acid profile of meat of lambs fed on silages of saccharine sorghum (‘BRS506’ and ‘BRS511’ varieties), forage sorghum and maize.

2. Material and Methods

2.1 Location, Animals and Diet

The analyses were performed in the Meat Quality and Carcass Evaluation, Management and Agricultural Waste laboratories of Federal University of Grande Dourados (UFGD) and the physicochemical analyses were performed in the laboratory of Embrapa Agropecuária Oeste. The experimental procedure was approved by the Committee of Ethics for the Use of Animals—CEUA (protocol no 33/2015) of the UFGD, Dourados, Mato Grosso do Sul (MS), Brazil.

Twenty male, uncastrated Suffolk lambs, with initial ages of 75 ± 15 days and initial weights of 21 ± 7 kg, were arranged in a completely randomised block design, fed different experimental diets (5 animals per treatment) and housed in individual stalls.

The isonitrogenous diets used were composed of roughage and concentrate in the proportion of 50:50. The concentrate was based on maize, soybean bran and minerals (Table 1). The diet was prepared for an average gain of 250 g day^{-1} , following the recommendations of the National Research Council (NRC, 2007). The experimental diets consisted of silages: forage sorghum (FORSOR), saccharine sorghum (‘BRS506’), saccharine sorghum (‘BRS511’) and maize (MAIZE), which were produced at the Brazilian Agricultural Research Corporation—EMBRAPA (EMBRAPA Agropecuaria Oeste), Dourados, MS.

Table 1. Ingredients and chemical composition of the diets supplied to lambs finished in feedlot

| Ingredients (kg) | Silage | | | |
|--|----------------------------|--------|--------|-------|
| | FORSOR | BRS506 | BRS511 | MAIZE |
| Roughage | 50.00 | 50.00 | 50.00 | 50.00 |
| Grain Maize | 32.30 | 32.30 | 32.30 | 34.80 |
| Soybean bran | 15.00 | 15.00 | 15.00 | 12.50 |
| Mineral premix | 1.00 | 1.00 | 1.00 | 1.00 |
| Lime | 1.00 | 1.00 | 1.00 | 1.00 |
| Urea | 0.47 | 0.47 | 0.47 | 0.47 |
| Ammonium Sulfate | 0.15 | 0.15 | 0.15 | 0.15 |
| Vitamin premix | 0.05 | 0.05 | 0.05 | 0.05 |
| Flowers of sulfur | 0.02 | 0.02 | 0.02 | 0.02 |
| 15% Lasalocid sodium | 0.01 | 0.01 | 0.01 | 0.01 |
| Nutrients % | Chemical composition (%DS) | | | |
| Dry matter | 33.90 | 35.06 | 36.45 | 34.60 |
| Mineral matter | 6.26 | 5.32 | 5.01 | 5.26 |
| Organic matter | 93.73 | 94.67 | 94.99 | 94.73 |
| Crude protein | 13.15 | 12.82 | 12.66 | 13.77 |
| Ether extract (EE) | 1.35 | 1.35 | 1.35 | 1.40 |
| Neutral detergent fiber (NDF) | 44.61 | 41.05 | 40.98 | 36.11 |
| Acidic detergent fiber (ADF) | 20.17 | 17.26 | 17.56 | 12.97 |
| Total digestible nutrients (TDN) | 70.32 | 69.09 | 70.25 | 74.66 |
| Total Calcium (g kg ⁻¹ diet) | 5.37 | 5.37 | 5.37 | 5.37 |
| Total phosphorus (g kg ⁻¹ diet) | 2.52 | 2.52 | 2.52 | 2.52 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 = saccharine sorghum silage; MAIZE = Maize silage.

The average final weight of the animals was 33.75 ± 1.34 kg at 70 days (experimental period in the feedlot); they were weighed under a 16 h period of fast of solids, and the slaughter was carried out in accordance with the legislation of the State Inspection Service in Brazil (Brasil, 2009). The carcasses were stored in a cold room at 4 °C for 24 h. Subsequently, the *longissimus thoracis et lumborum* (LTL) muscle was removed from the carcasses and maintained at -18 °C for further analysis.

2.2 Instrumental Analysis of Meat

The pH values (pH₂₄) were obtained using a pH meter with a 205/206 penetration probe, at 24 h after slaughter, according to Monteschio et al. (2018).

Meat colour determinations were performed as described by Monteschio et al. (2018), evaluating the brightness (L *), the intensity of the red colour (a *) and the intensity of the yellow colour (b *) with a colorimeter (Minolta CR400 Chroma) after 30 minutes of sample exposure and the angle of exposure. Hue (HUE) and saturation index (Chroma) were

determined by the following formula: Chroma = $(a * 2 + b * 2)$ and hue angle (h°) = $(\arctan(b * / a *))$. The water retention capacity (WRC) was evaluated according to the method described by Hamm (1961), wherein each meat sample was weighed before and after a force had been exerted on it, and the WRC was calculated by the amount of water lost. The result was expressed as percentage of retained water in relation to the initial sample weight.

Samples of 2.5 cm of the *longissimus thoracis et lumborum* muscle were baked in an electric oven that was preheated to 170 °C, until the temperature of the geometric centre of the samples reached 70 °C, which was monitored using a digital thermometer. The weight loss by cooking (WLC) was obtained by the difference between the raw sample weight and cooked sample weight; the values were used to calculate the total losses and were expressed as percentages (Monteschio et al., 2018).

These samples were cooled at room temperature and used to determine the shear force according to Hopkins, Toohey, Warner, Kerr, & Van De Ven (2010), using a texture analyser (TA-XT2i) with a Warner-Bratzler blade in samples of 1.3 cm in diameter that were cut longitudinally to the fibres. The mean cut force of the cylinders was calculated to represent the shear force of the muscle and expressed in kgf.

2.3 Fatty Acids

The fatty acid profile was analysed on samples of the *longissimus thoracis et lumborum* muscles, which were lyophilised for 72 h, and the total lipids were extracted with a chloroform/methanol mixture (section 2.10), according to Kempinski et al. (2017). The fatty acids compositions were determined by gas chromatography, using a gas chromatograph with an ionisation detector flame (Alves, Argandoña, Linzmeier, Cardoso, & Macedo, 2016). For elution, a 100 m × 0.25 mm × 0.2 µm fused silica capillary column was used. The methyl esters of fatty acids were identified by comparison of retention times of the sample compounds with the standards (Sigma) eluted under the same conditions as the samples.

2.4 Centesimal Composition

The centesimal composition of the meat was evaluated using samples of the *longissimus thoracis et lumborum* muscle, which were removed and packed in polyethylene packages, identified and stored at -18 °C, according to Moura et al. (2017), to determine their dry matter, crude protein, lipids and mineral matter contents, according to the methodologies of the AOAC (1990).

2.5 Sensory Analysis

The sensory analysis was carried out in accordance with the CEP (n° 334.478) CAAE (Certificate of Presentation for Ethical Assessment 14870613.0.0000.5160) by using 2.5 cm samples of the *longissimus thoracis et lumborum* muscle. These samples were baked in an electric oven that was preheated at 170 °C, until the temperature of the geometric centre of the samples reached 70 °C, which was monitored with a digital thermometer. Subsequently, the samples were packed in laminated paper, identified and served to a panel of untrained tasters who evaluated the following sensory attributes: flavour (flavour intensity associated

with the ovine species), odour (intensity of smell associated with the sheep species), meat tenderness (texture felt as the meat was chewed) and global appreciation (evaluation of the samples adding all the parameters in general), using a non-structured hedonic scale of 10 points (0 to 10) (Devincenzi, Prunier, Meteau, & Prache, 2019). Mineral water at room temperature and unsalted biscuits were served to the tasters between the sample tastings to remove the residual flavour of the meat. A total of 110 tasters with ages between 17 and 36 years (56.36% women; 43.64% men) participated in the sensory analysis.

2.6 Statistical Analysis

The experiment was in a completely randomised block design, with four treatments and five replications. The attributes were evaluated by analysis of variance, using the MEANS and GLM (general linear model) procedures in the Minitab 17 program. Means and standard errors of the mean were calculated for each variable. The means were compared by the Tukey test ($p < 0.05$).

3. Results

The present data showed that there were no significant differences ($p > 0.05$) between the treatments for some of the lamb meat characteristics such as pH₂₄, WRC, WLC, shear force (SF) and colour of the meat (Table 2).

Table 2. Effect of different sorghum and maize silages on the meat characteristics of lambs finished in feedlots

| Parameters | Silage | | | | MSE | P-value |
|-------------------|--------|--------|--------|-------|------|---------|
| | FORSOR | BRS506 | BRS511 | MAIZE | | |
| pH ₂₄ | 5.62 | 5.57 | 5.46 | 5.56 | 0.05 | 0.35 |
| WRC (%) | 49.24 | 51.76 | 48.87 | 46.28 | 1.77 | 0.24 |
| WLC (%) | 37.56 | 43.20 | 35.03 | 37.54 | 2.78 | 0.29 |
| Shear Force (kgf) | 3.36 | 3.27 | 3.31 | 3.40 | 0.35 | 1.00 |
| L* | 36.49 | 35.27 | 36.49 | 36.33 | 0.78 | 0.67 |
| a* | 16.25 | 17.33 | 16.61 | 16.71 | 0.34 | 0.29 |
| b* | 6.69 | 7.56 | 7.10 | 7.60 | 0.35 | 0.30 |
| HUE* | 22.36 | 25.20 | 23.06 | 23.53 | 1.28 | 0.52 |
| Chroma* | 17.58 | 18.92 | 18.09 | 18.37 | 0.41 | 0.25 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 =

saccharine sorghum silage; MAIZE = Maize silage. MSE = Mean standard error; WRC = water retention capacity; WLC = weight loss by cooking; L* = luminosity; a* = intensity of red color; b* = intensity of yellow color; *HUE = hue angle; *Chroma = saturation index.

The meat chemical composition of the evaluated lambs was not affected by the treatments; no significant differences ($p > 0.05$) were found for the chemical composition of the *longissimus thoracis et lumborum* (Table 3), with means of moisture, ash, protein and ether extracts of 76.19%, 1.45%, 14.09% and 3.23%, respectively.

Table 3. Effect of different sorghum and maize silages on the chemical composition of the LTL muscle of lambs finished in feedlots

| Parameters | Silage | | | | MSE | P-value |
|---------------------|--------|--------|--------|-------|------|---------|
| | FORSOR | BRS506 | BRS511 | MAIZE | | |
| Moist (%) | 76.22 | 76.21 | 75.72 | 76.62 | 0.69 | 0.78 |
| Ash (%NM) | 1.15 | 1.15 | 1.18 | 1.13 | 0.05 | 0.91 |
| Protein (%DM) | 13.78 | 14.12 | 14.32 | 14.17 | 0.53 | 0.89 |
| Ether extract (%NM) | 3.27 | 3.27 | 3.22 | 3.16 | 0.34 | 1.00 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 = saccharine sorghum silage; MAIZE = Maize silage. MSE = Mean standard error; NM = natural matter; DM = dry matter.

Table 4. Effect of different sorghum and maize silages on the sensory characteristics of the LTL muscle of lambs finished in feedlots

| Parameters | Silage | | | | MSE | P-value |
|----------------------|--------|--------|--------|-------|------|---------|
| | FORSOR | BRS506 | BRS511 | MAIZE | | |
| Flavor | 6.54 | 6.42 | 7.06 | 6.58 | 0.22 | 0.25 |
| Odor | 6.40 | 6.57 | 6.72 | 6.69 | 0.24 | 0.79 |
| Tenderness | 7.93 | 7.47 | 7.59 | 7.50 | 0.20 | 0.32 |
| Overall appreciation | 7.08 | 6.61 | 7.23 | 7.15 | 0.19 | 0.10 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 = saccharine sorghum silage; MAIZE = Maize silage. MSE = Mean standard error.

The results of the sensory analysis parameters of the LTL muscle showed no difference between treatments ($p > 0.05$) (Table 4), with means for flavour, odour, tenderness and overall appreciation of 7.01, 6.65, 5.97, 6.59, 7.62 and 7.01, respectively.

The treatments presented differences ($p < 0.05$) in the classification of saturated fatty acids for the caproic (C10:0), myristic (C14:0), pentadecanoic (C15:0), palmitic (C16:0), heptadecanoic (C 17:0), stearic (C 18:0) and total saturated fatty acids (Table 5). The lowest levels of C14:0 and C17:0 fatty acids (2.55% and 1.41%, respectively) were found in the meat of animals fed with 'BRS511' saccharine sorghum silage, and the lowest levels of C16:0 and C18:0 saturated fatty acids and total saturated fatty acids were found in animals fed with 'BRS506' saccharine sorghum silage (Table 5).

Table 5. Effect of different sorghum and maize silages on the saturated fatty acid composition in the LTL muscle of lambs finished in feedlots

| Parameters | Treatments | | | | MSE | P-value |
|---------------------|--------------------|--------------------|--------------------|--------------------|------|---------|
| | FORSOR | BRS506 | BRS511 | MAIZE | | |
| Capric C10:0 | 0.10 ^b | 0.10 ^{ab} | 0.11 ^a | 0.11 ^a | 0.00 | 0.01 |
| Lauric C12:0 | 0.12 ^a | 0.12 ^a | 0.12 ^a | 0.12 ^a | 0.00 | 0.34 |
| Myristic C14:0 | 2.83 ^a | 2.74 ^a | 2.55 ^b | 2.78 ^a | 0.02 | <0.001 |
| Pentadecanoic C15:0 | 0.23 ^a | 0.21 ^{bc} | 0.22 ^{ab} | 0.19 ^c | 0.01 | <0.001 |
| Palmitic C16:0 | 24.01 ^a | 23.09 ^b | 23.85 ^a | 24.05 ^a | 0.05 | <0.001 |
| Heptadecanoic C17:0 | 1.52 ^a | 1.46 ^{bc} | 1.41 ^c | 1.52 ^{ab} | 0.01 | <0.001 |
| Stearic C18:0 | 18.20 ^b | 18.37 ^b | 18.97 ^a | 18.27 ^b | 0.11 | <0.001 |
| Arachidonic C20:0 | 0.11 ^a | 0.11 ^a | 0.11 ^a | 0.11 ^a | 0.00 | 0.72 |
| Total saturated | 47.14 ^a | 46.22 ^b | 47.31 ^a | 47.17 ^a | 0.14 | <0.001 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 = saccharine sorghum silage; MAIZE = Maize silage. MSE = Mean standard error. Means followed by the same letter in the row do not differ at 5% probability.

Table 6. Effect of different sorghum and maize silages on the monounsaturated and polyunsaturated fatty acid compositions in the LTL muscle of lambs finished in feedlots

| Parameters | Treatments | | | | MSE | P-value |
|----------------------------|--------------------|--------------------|--------------------|--------------------|------|---------|
| | FORSOR | BRS506 | BRS511 | MAIZE | | |
| Myristoleic C14:1 | 0.10 ^a | 0.11 ^a | 0.11 ^a | 0.11 ^a | 0.00 | 0.70 |
| Palmitoleic C16:1 | 1.62 ^a | 1.57 ^b | 1.59 ^{ab} | 1.58 ^b | 0.01 | 0.01 |
| Oleic C18:1 | 44.21 ^b | 44.91 ^a | 43.91 ^b | 43.84 ^b | 0.15 | <0.001 |
| Linoleic C18:2 ω 6 | 3.44 ^b | 3.55 ^a | 3.59 ^a | 3.56 ^a | 0.02 | <0.001 |
| Linolenic C18:3 ω 3 | 0.18 ^{ab} | 0.18 ^{ab} | 0.16 ^b | 0.18 ^a | 0.00 | 0.03 |
| Eicosenoic C20:1 | 0.10 ^a | 0.10 ^a | 0.10 ^a | 0.10 ^a | 0.00 | 0.47 |
| Eicosadienoic C20:2 | 0.10 ^a | 0.10 ^a | 0.11 ^a | 0.10 ^a | 0.00 | 0.70 |
| Eicosatrienoic a C20:3 ω 6 | 0.10 ^a | 0.10 ^a | 0.10 ^a | 0.10 ^a | 0.00 | 0.91 |
| Eicosatrienoic b C20:3 ω | 1.40 ^b | 1.50 ^{ab} | 1.50 ^{ab} | 1.61 ^a | 0.02 | <0.001 |
| Arachidonic C20:4 | 0.19 ^a | 0.19 ^a | 0.19 ^a | 0.19 ^a | 0.00 | 0.68 |
| Eicosapentaenoic C20:5 | 0.10 ^a | 0.10 ^a | 0.10 ^a | 0.11 ^a | 0.00 | 0.46 |
| n-6 | 3.51 ^b | 3.65 ^a | 3.73 ^a | 3.66 ^a | 0.02 | <0.001 |
| n-3 | 1.68 ^b | 1.76 ^{ab} | 1.76 ^{ab} | 1.86 ^a | 0.03 | <0.001 |
| Total unsaturated | 52.86 ^b | 53.80 ^a | 52.67 ^b | 52.85 ^b | 0.14 | <0.001 |
| Total monounsaturated | 46.96 ^b | 47.66 ^a | 46.40 ^b | 46.55 ^b | 0.14 | <0.001 |
| Total polyunsaturated | 5.91 ^b | 6.14 ^a | 6.27 ^a | 6.30 ^a | 0.04 | <0.001 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 = saccharine sorghum silage; MAIZE = Maize silage. MSE = Mean standard error. Means followed by the same letter in the row do not differ at 5% probability.

Differences were found for total monounsaturated and unsaturated fatty acid contents ($p < 0.05$). Oleic fatty acid (C18:1) represented 44.91% of the total unsaturated fatty acid composition (Table 6). Higher levels of C18:1, total unsaturated and total monounsaturated fatty acids were found in the meat of animals treated with 'BRS506', and lower levels of C18:2 ω 6 linoleic, n-6 and total polyunsaturated fatty acids were found in the treatment with forage sorghum (Table 6). No differences were found between treatments ($p > 0.05$) for the nutritional and functional classifications and enzymatic activities in the lambs' meat (Tables 7 and 8).

Table 7. Effect of different sorghum and maize silages on the nutritional classification of fatty acids as of function of their relations in the LTL muscle of lambs finished in feedlots

| Parameters | Silage | | | | MSE | P-value |
|---------------------------|--------|--------|--------|-------|------|---------|
| | FORSOR | BRS506 | BRS511 | MAIZE | | |
| Omega 6:3 | 2.03 | 2.11 | 2.07 | 2.04 | 0.03 | 0.43 |
| Unsaturated:Saturated | 1.13 | 1.12 | 1.12 | 1.15 | 0.01 | 0.17 |
| Monounsaturated:Saturated | 1.00 | 0.99 | 0.99 | 1.02 | 0.01 | 0.13 |
| Polyunsaturated:Saturated | 0.13 | 0.13 | 0.13 | 0.13 | 0.00 | 0.80 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 = saccharine sorghum silage; MAIZE = Maize silage. MSE = Mean standard error.

Table 8. Effect of different sorghum and maize silages on the functional fatty acid composition and enzyme activity in the LTL muscle of lambs finished in feedlots

| Parameters | Silage | | | | MSE | P-value |
|------------------------------------|--------|--------|--------|-------|------|---------|
| | FORSOR | BRS506 | BRS511 | MAIZE | | |
| Hypercholesterolemics ¹ | 28.31 | 28.43 | 28.41 | 28.02 | 0.20 | 0.49 |
| Hypocholesterolemics ² | 48.83 | 48.58 | 48.53 | 49.12 | 0.22 | 0.29 |
| Neutrals ³ | 18.40 | 18.53 | 18.81 | 18.48 | 0.18 | 0.47 |
| Residuals ⁴ | 1.80 | 1.81 | 1.79 | 1.79 | 0.03 | 0.94 |
| Thrombogenicity ⁵ | 0.68 | 0.69 | 0.69 | 0.68 | 0.01 | 0.68 |
| Atherogenicity ⁶ | 0.35 | 0.35 | 0.35 | 0.35 | 0.00 | 0.97 |
| Δ9-desaturase C:16 | 6.26 | 6.27 | 6.28 | 6.29 | 0.05 | 0.98 |
| Δ9-desaturase C:18 | 70.77 | 70.52 | 70.13 | 70.82 | 0.27 | 0.32 |
| Elongase | 71.15 | 71.04 | 71.07 | 71.57 | 0.20 | 0.30 |

FORSOR = Forage sorghum silage; BRS506 = saccharine sorghum silage; BRS511 = saccharine sorghum silage; MAIZE = Maize silage. MSE = Mean standard error. ¹(C12:0 + C14:0 + C16:0); ²(C18:1 + C18:1 cis 9 + C18:2 cis-9,12 + C18:3 cis-9, 12, 15 + ω 6 + ω 3); ³(C14:1 + C16:1 + C18:0 + C10:0); ⁴(AG branched C15:0; C17:0 C18:1 cis C18:2 isomers); ⁵((C14:0 + C16:0 + C 18:0)/[(0,5 x ΣAGMI) + (0,5 x Σω6) + (3 x Σω3) + (Σω3/ Σω6)]); ⁶([(C12:0 + (4 x C14:0) + C 16:0]/(ΣAGM-I + Σω6 + Σω3)).

4. Discussion

4.1 Qualitative Characteristics

The mean pH of the meat samples at 24 h after slaughter was within the normal range (5.5 and 5.6) (Page, Wulf, & Schwotzer, 2001). It should be emphasised that normal pH values suggest that other indicative parameters of meat quality, such as colour and texture, will have good results (Bonagurio, Pérez, Garcia, Bressan, & Lemos, 2003).

Meat colour is the most acceptable parameter of meat freshness and quality by consumers and is an important sensory aspect of meat (Bressan, Prado, Pérez, Lemos, & Bonagurio, 2001). The results of meat colour found in the present study are consistent with those reported by Bressan et al. (2001), who found L* of 30.0–49.5, a* of 8.2–23.5 and b* of 3.4–11.1.

According to Khliji, Van De Ven, Lamb, Lanza, & Hopkins (2010), the acceptable limit for L* in lamb meat is 34 to 35, which is similar to the values found in the present study (35.89) and lower than that (39.16) reported by Campos et al. (2017) in meat of lambs fed with different silages.

The mean values of lamb meat tenderness found in the present study (3.33 kgf) are classified as soft (Tatum, Smith, & Belk, 2000). Similar result was reported by Lara, Bragiato, Rabelo, Messana, & Reis (2018), who found mean of 3.00 kgf when evaluating the meat quality of lambs fed with maize silage.

Meat tenderness is the result of several factors, such as species, breed, age, meat fat, and muscle fibres post-mortem of the animal (Saccà, Corazzin, Bovolenta, & Piasentier, 2019). It is an important factor in meat quality and affects its acceptability by the consumer (Arguello, Castrol, Sanchez-Maciasi, & Capote, 2012).

4.2 Centesimal Analysis

The results were similar to others reported in the literature. According to Madruga, Sousa, Rosales, Cunha, & Ramos (2005), sheep meat chemical composition consists, on average, of 75% moisture, 19% protein, 4% fat and 1% mineral matter, with possible variations in these levels depending on the age, genotype, sex, castration, pre and post-slaughter management and diet of the animal (Tshabalala, Strydom, Webb, & De Kock, 2003).

He, Wu, Wang, Meng, & Zhou (2018), Campos et al. (2017) and Lara et al. (2018) found no differences in the chemical composition of lamb meat receiving different silages in their diets. These are similar results to those found in the present study, in which only the fat content was higher (3.23%) than those found by those previous authors. According to Bezerra et al. (2016), this value characterises the meat as lean because of a fat content of less than 5%.

4.3 Sensory Analysis

There were no differences between the means attributed to the sensory characteristics of the evaluated lamb meat. The palatability of the meat is generally described in terms of tenderness, juiciness and flavour notes (Thompson et al., 2005). Madruga et al. (2005) evaluated different silages and hays and found differences between treatments, with higher values for sheep odour (4.87) and lipid content (8.38) in the meat of animals treated with maize silage. These results were lower than that found in the present study for sheep odour (6.69) and higher than that found for ethereal extract (3.16%) in the meat of animals fed with maize silage. This confirms the importance of lipids in the formation of the meat odour characteristics (Madruga et al., 2002; Mottram, 1998). The characteristics odour and flavour of meat are directly related to the fat content present in the muscles (Madruga, 1997).

4.4 Fatty Acid Composition

The fatty acids found in the highest concentrations were palmitic (23.75%), stearic (18.45%) and myristic (2.72%) saturated fatty acids, oleic monounsaturated (44.21%) and linoleic polyunsaturated (53%), constituting 92.66% of the total fatty acids of the evaluated lamb meat. High concentrations of these fatty acids in the lamb meat was also found by Leão et al.

(2011) when evaluating the effect of maize silage on the meat fatty acid composition.

Myristic (C14:0) and palmitic (C16:0) saturated fatty acids are hypercholesterolemic, but the stearic acid (C18:0), which represents 10 to 20% of the fat produced by ruminants, does not have this property (Leão et al., 2011). According to Novello, Franceschini, & Quintiliano (2008), unlike other saturated fatty acids, C18:0 is classified as non-atherogenic (neutral), showing that the increase of this fatty acid in the meat of animals fed with 'BRS511' silage is not harmful for human consumption; the meat of the animals of this treatment had low C14:0 and C16:0 and high C18:0 contents.

Mono and polyunsaturated fatty acids are beneficial to human health (Perini et al., 2010). According to Cooper et al. (2004), the diet may alter the percentage of palmitoleic (C16:1 ω 7) and oleic (C18:1 ω 9) acids in the meat. The highest percentages ($p < 0.05$) of oleic acid were found in the meat of lambs finished with the 'BRS506 silage'. The highest percentages ($p < 0.05$) of palmitoleic acid were found in animals treated with forage sorghum, which did not differ from the meat of animals treated with 'BRS511' silage.

Not all saturated fatty acids are hypercholesterolemic (which increase LDL cholesterol); the most undesirable fatty acid would be the myristic (C14:0), which presented the lowest mean (2.55%) in the meat of animals fed with 'BRS511 silage'. The palmitic acid (C16:0) had a mean of 23.75% of the total fatty acids; according to Fernandes et al. (2010) and French, O'riordan, Monahan, Caffrey, & Moloney (2003), it has the lowest hypercholesterolemic effect. Stearic acid (C18:0) was an average of 18.45% of the total fatty acids; its effect is null, since it is converted to oleic acid (C18:1) in the organism (Sinclair, 1993) without affecting the blood cholesterol levels. The treatment with 'BRS511' resulted in the lowest percentage of total saturated fatty acids in the lamb meat (46.22%).

On average, the amounts of unsaturated (53.04%), monounsaturated (46.89%) and polyunsaturated (6.15%) fatty acids indicate that lamb meat is rich in "good" fat, confirming the results found by Monteiro, Fernandes, & Barros (2007) and Leão et al. (2011).

The polyunsaturated/saturated ratio (PUFA:SFA) of the lamb meat (0.13) (Table 7) was below the ideal level (0.40) to be considered a healthy food, as recommended by the Department of Health of the United Kingdom to avoid diseases associated with the consumption of saturated fats (Wood et al., 2004). According to Scollan et al. (2001) and Scollan et al. (2006), the PUFA:SFA ratio in meat is generally low (0.1) and varies between 0.06 and 0.15; the nutritional management does not increase the PUFA:SFA ratio above the normal level because of the high biohydrogenation degree of polyunsaturated compounds in the rumen. Fernandes et al. (2010) and Leão et al. (2011) did not find significant effects on the PUFA:SFA ratio in animals fed with maize silage or sugarcane silage.

Thrombogenicity indexes, with a mean of 0.68, were within the range recommended by Ulbricht & Southgate (1991), who indicate a maximum amount of 1.27. The atherogenicity index was also lower (0.35) than those recommended for human health (0.72). Ulbricht & Southgate (1991) proposed these indexes for comparison of diets and foods that participate in possible causes of coronary diseases, mainly related to saturated fatty acids.

5. Conclusions

Saccharin sorghum silages do not alter the chemical, qualitative and sensory characteristics of lamb meat, which indicates that these silages can be used for feeding finishing lambs and can replace maize silage.

The ‘BRS506’ saccharin sorghum silage also increases total unsaturated and monounsaturated fatty acids in the lamb meat, which are beneficial to human health.

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