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Instrumental and sensory evaluation of meat from lambs and hoggets fed high-concentrate maize or sorghum diets

Avaliação instrumental e sensorial da carne de cordeiros e borregos alimentados com dietas de alto concentrado de milho ou sorgo

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Highlights:
Lamb meat showed better results for color quality traits.
Hoggets had more appealing results, given the less acidic taste of their meat.
Maize grain provided superior meat quality in terms of instrumental traits.
Sorghum grain provided softer meat with lower strange-aroma perception.

Abstract

Instrumental and sensory traits of meat from lambs and hoggets fed high-concentrate maize or sorghum diets were evaluated. A total of 16 lambs and 16 hoggets were used in a completely randomized experimental design with a 2 × 2 factorial arrangement (two sheep categories × two grain types). Lamb meat exhibited greater lightness (L*) in the *rectus abdominis* muscle (RA); yellow intensity (b*) in the perirenal fat (PF) and subcutaneous caudal fat (SCF); and water-holding capacity and acidic taste in the *longissimus dorsi* (LD) muscle. Hogget meat, on the other hand, showed higher ($P < 0.05$) red indices (a*) (RA), cooking losses (kg) and drip losses (kg and g kg^{-1}) (LD). Between the diets, the maize diet resulted in higher values ($P < 0.05$) for a* content (PF and SCF) and strange aroma (LD) of meat. The sorghum diet provided meat with higher cooking (kg) and drip (kg) losses and greater tenderness (LD) ($P<0.05$). Therefore, while the lamb category and the maize grain diet favored the instrumental traits, the hogget category and sorghum grain diets benefited the sensory traits of meat.
Key words: Carcass. Category. Grain. Meat tenderness. Sheep.

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Resumo

Avaliaram-se as características instrumentais e sensoriais da carne de cordeiros e borregos alimentados com dietas de alto concentrado de milho ou sorgo. Foram utilizados 16 cordeiros e 16 borregos, distribuídos em delineamento experimental inteiramente casualizado, em esquema fatorial 2 x 2 (duas categorias ovinas x dois tipos de grãos). A carne dos cordeiros apresentou superioridade para luminosidade (L*) no músculo *rectus abdominis* (RA), índice de amarelo (b*) na gordura perirenal (GR) e na gordura subcutânea caudal (GSC), capacidade de retenção de água e sabor ácido no músculo *longissimus dorsi* (LD). Por outro lado, borregos apresentaram índice de vermelho (a*) (RA), perdas a cocção (kg) e perdas de exudato (kg e g kg^{-1}) (LD) superiores ($P < 0,05$). Ao avaliar as dietas, os animais alimentados com grão de milho apresentaram resultados superiores ($P < 0,05$) para o teor de a* (GR e GSC) e aroma estranho (LD). Os animais alimentados com grão de sorgo apresentaram perdas a cocção (kg), perdas de exudato (kg) e maciez (LD) superiores ($P < 0,05$). Portanto, enquanto que a categoria cordeiros e a dieta com grão de milho favoreceram melhores características instrumentais, a categoria borregos e dietas com grão de sorgo apresentaram melhores características sensórias da carne.

Palavras-chave: Carcaça. Categoria. Grão. Maciez da carne. Ovinos.

Introduction

The search for sheep meat has risen mainly due to the demand from large urban centers, which has allowed the expansion of the activity and resulted in greater profitability for sheep farmers. Considering the growing development of agricultural areas, intensifying animal production areas appears to be an interesting strategy. In this scenario, the practice of feedlotting has been increasingly adopted in sheep farming systems (Bernardes et al., 2015).

There has been considerable progress in animal nutrition in recent years, as the supplied diets properly meet nutritional requirements. As a consequence, excellent results have been achieved in the production of high-quality meat. In this respect, maize is the most widely used ingredient in the formulation of animal diets, although sorghum can be employed as an alternative. Venturini et al. (2016) mentioned that these grains are very well-accepted by animals and largely available for producers.

Herd composition is an important factor to be considered in a sheep production system, since animals of different ages (categories) are slaughtered and sold and consumers are highly demanding in terms of meat quality. Parameters analyzed in instrumental and sensory evaluations of meat such as water-holding capacity, tenderness, aroma, taste and juiciness are used to measure meat quality (Guerrero, Valero, Campo, & Sañudo, 2013). The demand for healthy food and the consumer demand for product quality have driven part of the market niche to consume meat of better nutritional and sensory quality (Costa, Cartaxo, Santos, & Queiroga, 2008).

The aim of this study was to undertake instrumental and sensory analyses of meat from lambs and hoggets fed high-concentrate maize or sorghum diets.

Material and Methods

This study was carried out at the Sheep Laboratory of the Department Animal Science of the Federal University of Santa Maria, located in Santa Maria - RS, Brazil, after approval by the Ethics Committee on Animal Use of the same institution (approval no. 059-2014).

The study involved 32 castrated male Corriedale sheep, consisting of 16 lambs (approximately 4 months old) and 16 hoggets (approximately 12 months) from the same herd. The animals were evaluated in a completely randomized experimental design with a 2 × 2 factorial arrangement (two sheep categories × two grains), with eight replicates per treatment. Treatments were represented by lambs fed a high-concentrate maize diet; lambs fed a high-concentrate sorghum diet; hoggets fed a high-concentrate maize diet; and hoggets fed a high-concentrate sorghum diet.

Lambs were confined in individual, fully covered, 2.0-m^2 stalls with slatted floors. All stalls were equipped with individual feeders and drinkers. The diet was formulated to be isoproteic, for each category, consisting of oat hay (*Avena sativa*) and whole grains of maize (*Zea mays*) or sorghum (*Sorghum bicolor* (L.) Moench). To meet the crude protein and mineral requirements of the animal categories, soybean meal (*Glycine max*) and calcitic limestone were added, respectively, as recommended by the National Research Council [NRC] (2007), to provide a weight gain of 200 g d^{-1}. Sodium bicarbonate ($NaHCO_3$; in the proportion of 1% of the total dry matter [DM] supplied), sodium monensin (Rumensin®; according to the manufacturer's recommendations) and common salt (sodium chloride [NaCl]; available *ad libitum* in individual containers) were also used. The diets were supplied once daily, at 08h00, as a total mixture, having a roughage-to-concentrate ratio of 10:90 (DM basis). The amount supplied was adjusted according to the daily orts, which were aimed at 10% of the amount supplied on the previous day, to ensure the maximum voluntary intake.

Table 1 shows the chemical composition of the ingredients and Table 2 describes the proportion of ingredients and chemical composition of the experimental diets.

Table 1
Mean dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), total carbohydrates (TC), non-structural carbohydrates (NSC), ash, total digestible nutrients (TDN), calcium (Ca) and phosphorus (P) contents of the ingredients used in the formulation of the experimental diets

Item (g kg^{-1})	Oat hay	Maize grain	Sorghum grain	Soybean meal	Sodium bicarbonate	Calcitic limestone	Sodium monensin
DM	899.90	909.80	907.00	925.00	990.00	992.70	980.00
OM	928.40	989.50	986.70	933.90	-	-	-
CP	59.40	89.60	84.20	523.00	-	-	-
EE	18.70	53.60	43.00	38.90	-	-	-
NDF	643.60	98.40	116.00	161.60	-	-	-
ADF	368.00	15.30	55.10	58.80	-	-	-
TC	850.20	846.40	859.60	372.00	-	-	-
NSC	206.70	747.90	743.50	210.40	-	-	-
Ash	71.60	10.50	13.30	66.10	-	-	-
TDN	555.80	860.30	788.00	807.30	-	-	-
Ca	4.40	0.30	0.40	3.30	-	377.00	-
P	2.40	2.50	2.80	8.80	-	0.20	-

Upon reaching a body condition score of 3.0 (scale of 1.0 to 5.0 with 0.25-point intervals, where 1.0 = emaciated and 5.0 = excessively fat), the lamb or hogget was weighed and then deprived of solid and liquid feed for 14 h. Subsequently, the animals were sent to slaughter after previous desensitization by a captive bolt pistol, which induced a rapid state of unconsciousness. The time from desensitization to bleeding did not exceed one minute, in accordance with Humane Slaughter standards. After the slaughter procedures, the carcasses were refrigerated in a cold room at 2 °C for 24 h.

Immediately after the carcasses were removed from the cold room, the *rectus abdominis* and *longissimus dorsi* muscles, perirenal fat and subcutaneous caudal fat, located in the lumbar region, were removed to determine color using a previously calibrated colorimeter (Minolta Chroma Meter CR-300; Minolta Camera Co. Ltd., Osaka, Japan) with a D65 illuminant. Results were expressed as L* (lightness), a* (red intensity) and b* (yellow intensity) coordinates.

Table 2
Proportion of ingredients (g kg^{-1} DM) and chemical composition of experimental diets

Ingredient, g kg^{-1} diet DM	Treatment			
	Lamb		Hogget	
	Maize	Sorghum	Maize	Sorghum
	Proportion of ingredients (g kg^{-1} DM)			
Oat hay	100.00	100.00	100.00	100.00
Maize grain	608.20	-	778.10	-
Sorghum grain	-	599.20	-	766.70
Soybean meal	260.40	268.10	94.80	104.70
Sodium bicarbonate	10.00	10.00	10.00	10.00
Calcitic limestone	21.10	22.40	16.70	18.30
Sodium monensin	0.34	0.34	0.34	0.34
	Chemical composition (g kg^{-1} DM)			
DM*	915.30	91.390	912.40	910.60
OM	969.00	96.680	978.20	975.50
CP	196.60	19.660	125.20	125.20
EE	44.60	38.10	47.20	38.90
NDF	166.30	177.20	156.30	170.20
ADF	61.40	85.60	54.30	85.20
TC	696.60	699.80	778.90	783.00
NSC	530.30	522.60	622.60	612.80
Ash	30.70	32.80	21.60	24.30
TDN	789.30	744.50	801.80	744.60
Ca/P	25.00	25.00	25.00	25.00

*Dry matter of the mixture.

The *longissimus dorsi* muscle was removed from each half carcass and separated into three aliquots, which were packed separately and stored at -18 °C. The region between the 6th and 10th dorsal vertebra was destined for the analysis of water-holding capacity (WHC). The last dorsal vertebrae region (approximately between the 11th and 13th vertebrae) was used to determine texture and the lumbar portion (approximately between the 1st and 6th lumbar vertebrae) was used for sensory analysis, both following the methodology proposed by Cañeque and Sañudo (2005).

Water-holding capacity was determined by following the methodology Hamm (1986), adapted by Osório, Osório and Jardim (1998), which consists of compressing three replicates of approximately 0.5 g of meat (previously ground and homogenized on paper of standard filter) with a 2.25-kg weight for 5 min. The meat sample resulting from this process was weighed on a precision scale and the amount of water lost was determined by difference. Results were expressed as a percentage of water lost relative to the initial weight of the sample.

Cooking (CL), evaporation (EL) and drip (DL) losses were analyzed in the loin region that comprises the last dorsal vertebrae. For this step, the *longissimus dorsi* muscle samples were cut into 2.54-cm-thick steaks, which were weighed, wrapped in aluminum foil and cooked on a preheated grill, where they remained until reaching an average internal temperature of 72 °C in their geometric center, which was monitored by a thermocouple. After cooling, the steaks were weighed again, to determine CL. Because the meat samples were wrapped in aluminum foil, it was possible to separate DL and EL during cooking, with their sum constituting the total CL. The losses were expressed as a percentage relative to the weight of the raw meat sample.

On the following day, the same samples were used to determine the Instrumental Texture Profile (Texture Profile Analysis - TPA) using an appropriate texture analyzer (TA-XT.plus) with a 36-mm-diameter P/36R metal probe. Data were measured using Texture Expert Exponent software (Stable Micro Systems Ltd., Surrey, England). The samples were cut in the direction of the muscle fibers into cubes of approximately 1.0 cm^3, generating an average of six sub-samples per steak. Subsequently, the texture analyzer was calibrated for the test, pre-test and post-test speeds and the cycle time following the methodology proposed by Huidobro, Miguel, Blazquez and Onega (2005). Shear force was also evaluated using the aforementioned texturometer operating with a Warner-Bratzler Shear Force blade at 20 cm/min, which measured the maximum force required to break the muscle fibers, with results expressed in kg F-cm^3. From each steak sample, an average of six meat sub-samples were extracted using a hollow cylinder (core) in the longitudinal direction of the muscle fibers. Sarcomere length was measured as proposed by Cross, West and Duntson (1981).

Sensory analysis of the meat was performed by the team of trained judges from the Meat Laboratory of Embrapa Pecuária Sul. For these analyses, *longissimus dorsi* muscle samples were thawed under refrigeration at approximately 4 ºC for 24 h. Subsequently, they were roasted together on grids preheated to 163 °C until reaching the temperature of 71 °C in their geometric center, which was measured using thermocouples and Flyever Mux 12 software. After roasting, the samples were cut into cubes of approximately 1.5 × 1.5 cm, wrapped in aluminum foil and kept heated in a conventional oven (in the sample preparation area) and in heaters inside the booths at a temperature of approximately 50 °C until the moment they were served and analyzed. The meat samples were coded with three-digit numbers and served sequentially to the trained judges in individual booths.

The descriptive test (qualitative descriptive analysis) was carried out with the aid of eight trained judges who used an unstructured scale to evaluate the following sensory attributes: characteristic aroma, strange aroma, characteristic taste, pork-like taste, metallic taste, rancid taste, acidic taste, sweetish taste, fat-like taste, tenderness and juiciness. These attributes were previously raised in a training session with the team of judges with five years of experience.

A complete-block experimental design was adopted for the treatments that composed the dishes offered to the judges, following the recommendations of Cochran and Cox (1992). The sample sequence was randomized, following Macfie, Bratchell, Greenhoff and Vallis (1989).

The experiment was laid out in a completely randomized design with a 2 × 2 factorial arrangement (two sheep categories × two grains). For the analysis of the data, the effects of sheep category, grain and category × grain interaction were evaluated by analysis of variance and F test, adopting the 5% significance level. The following mathematical model adopted:

$$Y_{ijk} = \mu + \alpha_i + ßj + (\alpha_* ß)_{ij} + \varepsilon_{ijk},$$

where Y_{ijk} = observation of animal k, of animal category i, fed high-grain diet j; μ = overall mean of observations; α_i = effect of animal category i (i = lamb or hogget); ßj = effect of high-concentrate diet j (j = maize or sorghum); $\alpha_* ß$ = interaction effect between category and grain; and ε_{ijk} = random error associated with each observation.

When the interaction effect between categories and grains was significant, means were compared by Student's t test. A correlation study between the dependent variables was carried out by calculating Pearson's correlation coefficients. Statistical analyses were performed using the SAS (2014) statistical package (version 9.4).

Results and Discussion

For all variables analyzed in this study, there was no interaction effect (P>0.05) between animal category (lamb or hogget) and high-concentrate diet (maize or sorghum). Therefore, the results will be presented independently.

No significant differences were found (P>0.05) for any of the variables measured in the *longissimus dorsi* muscle, for neither category nor grain (Table 3). Between the categories (lamb and hogget), in the variables evaluated in the *rectus abdominis* muscle, the lambs were superior (P<0.0001) for lightness (L*), but showed lower (P=0.0067) red intensity (a*) values than the hoggets. Pinheiro, Silva Sobrinho, Souza and Yamamoto (2009) commented that animal maturity influences the transfer of oxygen in the muscle fiber, as older animals have a greater amount of intramuscular fat and, consequently, less capillary permeability, requiring greater proportions of myoglobin in the muscle to ensure oxygen supply. Gao et al. (2014) stated that myoglobin is related to the color of meat, and so younger animals (lambs) produce meat with a lighter tone (L*), whereas meat from older animals (hoggets) has a higher red intensity (a*), as found in the present study. Higher (P<0.05) yellow intensity (b*) values in the perirenal (P=0.0017) and subcutaneous caudal (P=0.0008) fats were found in hogget meat, compared with lamb. According to Rota et al. (2006), older animals have yellower fat due to the deficiency of the xanthophyll oxidase enzyme that occurs with the advance of age. However, although perirenal fat is deposited early in the animal, it is not practical for evaluation, whereas subcutaneous caudal fat can be more easily removed for the desired measurements.

There was a significant difference between the evaluated grains (maize or sorghum) for red intensity (a*), with higher values seen in the sheep fed sorghum grain compared with those fed maize grain, in both the perirenal fat (P=0.0463) and subcutaneous caudal (P=0.0220) fats. Xanthophylls and carotenes are the main pigments responsible for the color of adipose tissue (Kirton, Crane, Paterson, & Clare, 1975). Rocha et al. (2008) mentioned that the sorghum grain has low contents of xanthophyll and carotene, which is responsible for fixing the yellow-orangish color in the fat. Thus, the red content (a*) of fat from the animals fed the sorghum diet tends to be higher.

Results for cooking (CL), evaporation (EL) and drip (DL) losses are described in Table 4.

Higher (P=0.0090) water-holding capacity (WHC) was observed in lamb meat, compared with hogget meat. As stated by Bianchini et al. (2007), the proportion of water is higher in young animals, but this proportion decreases in muscles with high marbling degrees and elevated fat contents. According to Bonacina, Osório, Osório, Correa and Hashimoto (2011), WHC is closely linked to the quality of meat, affecting it before and during cooking and thus influencing its juiciness and, consequently, chewiness.

Table 3
Lightness (L*), red intensity (a*) and yellow intensity (b*) of the *longissimus dorsi* and *rectus abdominis* muscles perirenal fat and subcutaneous caudal fat of hoggets and lambs fed high-concentrate maize or sorghum diets

Variable	Lamb category		Grain		Probability			CV† (%)
	Lamb	Hogget	Maize	Sorghum	Category	Grain	Category × Grain	
Longissimus dorsi								
L*	40.35	39.35	40.12	39.58	0.2710	0.5428	0.1798	6.28
a*	23.01	23.10	23.22	22.89	0.7819	0.2835	0.1405	3.27
b*	4.24	4.74	4.74	4.21	0.0848	0.0533	0.0528	16.14
Rectus abdominis								
L*	48.17	44.27	46.32	46.11	<.0001	0.7677	0.1769	4.32
a*	25.47	28.23	27.10	26.60	0.0067	0.6016	0.3650	9.92
b*	6.01	6.37	6.29	6.09	0.3466	0.5603	0.0581	10.91
Perirenal fat								
L*	73.66	73.87	73.95	73.56	0.7176	0.5369	0.5670	2.33
a*	13.46	12.88	12.53	13.83	0.3311	0.0463	0.9234	13.33
b*	8.76	10.61	9.73	9.64	0.0017	0.8761	0.9926	15.54
Subcutaneous caudal fat								
L*	69.14	70.13	70.66	68.55	0.3146	0.0514	0.0554	3.81
a*	15.06	14.55	13.75	15.94	0.5998	0.0220	0.3027	16.60
b*	9.50	11.68	10.82	10.36	0.0008	0.4395	0.9812	15.44

†CV: coefficient of variation (P<0.05).

Table 4
Water holding capacity (WHC), cooking loss (CL), evaporation loss (EL) and drip loss (DP), expressed in absolute and relative values, of meat from hoggets and lambs fed high-concentrate maize or sorghum diets

Variable	Lamb category		Grain		Probability			CV† (%)
	Lamb	Hogget	Maize	Sorghum	Category	Grain	Category × Grain	
WHC	67.80	64.24	66.80	65.07	0.0090	0.2169	0.5414	5.28
CL (g)	5.70	7.02	5.80	6.92	0.0003	0.0019	0.0870	14.45
CL (g kg^{-1})	25.41	27.07	25.35	27.14	0.0958	0.0773	0.5144	10.80
EL (g)	2.93	3.17	3.00	3.10	0.5333	0.7991	0.2845	34.68
EL (g kg^{-1})	13.44	12.61	13.61	12.38	0.4800	0.2616	0.2311	24.41
DL (g)	2.55	3.85	2.67	3.73	<.0001	0.0006	0.6284	24.01
DL (g kg^{-1})	11.30	13.94	11.59	13.63	0.0216	0.0673	0.2016	24.05

†CV: coefficient of variation (P<0.05).

The hogget category showed the highest CL (P<0.05). According to Rubiano et al. (2009), this is because CL decreases as WHC increases. The correlation coefficient between WHC and CL found in this study (r=-0.42; P=0.0206) is in agreement with the previous statement. Likewise, DL expressed in both absolute and relative values was higher (P<0.05) in hogget meat compared with lamb. This result can be explained by WHC, considering that a lower WHC of meat implies losses of nutritional value through the released exudate, resulting in drier, tougher meat (Zeola, Souza, Souza, Silva Sobrinho, & Barbosa, 2007).

When the results were analyzed in relation to the tested grains (maize and sorghum), higher ($P<0.05$) absolute CL values were found in the meat from lambs fed sorghum grain than in the lambs fed the maize-based diet. Costa et al. (2011) mentioned that CL is an important factor to be taken into account by the consumer, as it is closely linked to the yield of meat during preparation. Additionally, higher DL (absolute values) ($P<0.05$) were seen in the meat from the animals fed sorghum, which is explained by the fact that cooking losses directly influence exudate release (drip loss). This statement is supported by the correlation coefficient between CL (g) and DL (g) found in the present study, which was high and significant ($r = 0.70$; $P<0.001$).

In terms of texture (TPA), the shear force and sarcomere length of the meat from lambs and hoggets fed high-concentrate maize or sorghum diets (Table 5) were not significantly influenced ($P>0.05$) by the evaluated categories or grain type used. The present results for shear force corroborate those reported by Silva Sobrinho, Purchas, Kadim and Yamamoto (2005), who described that sarcomere length has an influence on the tenderness of meat. These authors worked with sheep slaughtered at different ages (150 and 300 days of life) and also did not find significant values ($P>0.05$) for this variable.

Table 5
Texture profile analysis of meat from hoggets and lambs fed high-concentrate maize or sorghum diets

Variable	Category		Grain		Probability			CV[†] (%)
	Lamb	Hogget	Maize	Sorghum	Category	Grain	Category × Grain	
Toughness[1]	180.04	193.70	195.34	178.39	0.3556	0.2537	0.0641	22.01
Cohesiveness[2]	0.39	0.40	0.40	0.38	0.5894	0.2132	0.2468	9.79
Chewiness[3]	72.23	79.69	80.58	71.98	0.2355	0.1732	0.0605	5.56
Shear force[4]	2.42	2.93	2.64	2.71	0.1306	0.8394	0.8806	34.80
Sarcomere length[5]	1.87	1.85	1.90	1.81	0.7983	0.2525	0.3466	10.59

[1]In N; [2]Non-dimensional; [3]In N/cm; [4]In kgf; [5] In µm (X±s)/Time (h).
[†]CV: coefficient of variation ($P<0.05$).

When the sensory quality of meat from sheep fed high-concentrate maize or sorghum diets was analyzed (Table 6), the group that consumed maize grain showed higher values ($P=0.0227$) for strange aroma. By contrast, the sheep fed the sorghum grain-based diet produced meat with a higher degree of tenderness ($P=0.0410$) than those fed maize grain. Between the lamb and hogget categories, lamb meat had a more acidic taste ($P=0.0054$) than hogget meat. The other tested variables did not differ significantly ($P>0.05$).

Osório, Osório and Sañudo (2009) stated that high-energy diets increase fatness, giving a more intense flavor (aroma + taste) to the meat. In this respect, the maize grain diet is superior in energy when compared with the sorghum diet (Table 2), which resulted in the more prominent strange aroma of the meat from the animals fed maize compared with sorghum. According to those researchers, sensory differences are more significant in underweight and younger animals. This fact was observed in the present study, where lamb meat had a more acidic taste than hogget meat. It is worth stressing that lambs are young animals undergoing tissue (bone, muscular and adipose) formation and growth. Thus, changes occurring in this phase tend to become more evident, as the tissues are under development and, consequently, more susceptible to influences. Ferrão, Bressan and Oliveira (2009) asserted that the feed is among the factors that most influence the taste of meat.

Table 6
Sensory quality of meat from hoggets and lambs fed high-concentrate maize or sorghum diets

Variable	Lamb category		Grain		Probability			CV[†] (%)
	Lamb	Hogget	Maize	Sorghum	Category	Grain	Category × Grain	
Aroma (0-9)								
Characteristic	4.96	5.52	4.97	5.50	0.7289	0.1889	0.8376	37.41
Strange	1.61	1.37	1.97	1.02	0.0906	0.0227	0.4441	133.81
Taste (0-9)								
Characteristic	4.86	5.44	4.80	5.50	0.1679	0.1054	0.6539	40.69
Pork-like	1.00	0.91	0.97	0.93	0.7254	0.1901	0.8800	14.03
Liver-like	0.96	0.88	0.75	1.09	0.9633	0.8045	0.2073	13.01
Metallic	1.64	1.59	1.74	1.48	0.3505	0.3211	0.5247	79.02
Rancid	0.58	0.37	0.66	0.29	0.1814	0.1516	0.2174	18.06
Acidic	1.10	0.86	1.13	0.82	0.0054	0.1202	0.4291	63.58
Sweetish	0.43	0.55	0.48	0.50	0.4866	0.4861	0.9926	17.07
Fat-like	2.03	1.85	2.01	1.87	0.4912	0.3912	0.9753	35.26
Texture (0-9)								
Tenderness	6.98	6.97	6.65	7.30	0.9040	0.0410	0.1824	21.97
Juiciness	4.20	4.91	4.31	4.79	0.2114	0.1090	0.0729	31.93

[†]CV: coefficient of variation ($P<0.05$).

Regarding meat tenderness, better results were obtained with sorghum diet than with the maize diet. According to Costa et al. (2008), tenderness constitutes the main item in the evaluation or appreciation of meat. This variable is correlated with the other factors and, numerically, hardness and shear force were lower in the meat from the animals fed sorghum. This influenced the tenderness results, which were superior for the sorghum grain-fed animals, as observed in the sensory evaluation.

Conclusions

Lamb meat has better instrumental qualitative attributes than hogget meat, as the former has more satisfactory results in terms of color and water-holding capacity. The sensory quality of lamb meat is more attractive from the consumer's point of view, considering its lower scores for acidic taste.

Sheep fed maize-based diets produce meat with superior instrumental traits when compared with sheep fed sorghum grain. However, the sensory quality of meat from animals fed sorghum grain-based diets shows more satisfactory results, given its greater tenderness and lower strange-aroma perception.

References

Bernardes, G. M. C., Carvalho, S., Pires, C. C., Motta, J. H., Teixeira, W. S., Borges, L. I.,... Venturini, R. S. (2015). Consumo, desempenho e análise econômica da alimentação de cordeiros terminados em confinamento com o uso de dietas de alto grão. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *67*(6), 1684-1692. doi: 10.1590/1678-4162-7934

Bianchini, W., Silveira, A. C., Jorge, A. M., Arrigoni, M. B., Martins, C. L., Rodrigues, E.,... Andrighetto, C. (2007). Efeito do grupo genético sobre as características de carcaça e maciez da carne fresca e maturada de bovinos superprecoces. *Revista Brasileira de Zootecnia*, *36*(6), 109-2117. doi: 10.1590/S1516-35982007000900022

Bonacina, M. S., Osório. M. T. M., Osório, J. C. S., Correa, G. F., & Hashimoto, J. H. (2011). Influência do sexo e do sistema de terminação de cordeiros Texel × Corriedale na qualidade da carcaça e da carne. *Revista Brasileira de Zootecnia, 40*(6), 1242-1249. doi: 10.1590/S1516-35982011000600012

Cañeque, V., & Sañudo, C. (2005). *Estandarización de las metodologías para evaluar la calidad del producto (animal vivo, canal, carne y grasa) en los ruminantes*. Madri: INIA.

Cochran, W. G., & Cox, G. M. (1992). *Experimental designs* (2nd ed.). New York: Johk Willey & Sons, Inc.

Costa, R. G., Cartaxo, F. Q., Santos, N. M., & Queiroga, R. C. R. E. (2008). Carne caprina e ovina: composição lipídica e características sensoriais. *Revista Brasileira de Saúde e Produção Animal*, *9*(3), 497-506.

Costa, R. G., Santos, N. M., Sousa, W. A., Queiroga, R. C. R. E., Azevedo, P. S., & Cartaxo, F. Q. (2011). Qualidade física e sensorial da carne de cordeiros de três genótipos alimentados com rações formuladas com duas relações volumoso:concentrado. *Revista Brasileira de Zootecnia*, *40*(8), 1781-1787. doi: 10.1590/S1516-35982011000800023

Cross, H. R., West, R. L., & Duntson, R. L. (1981). Compairison of methods for measuring sarcomere length in beef semitendinosus muscle. *Meat Science, 5*(4), 261-266. doi: 10.1016/0309-1740(81)90016-4

Ferrão, S. P. B., Bressan, M. C., Oliveira, R. P., & Perez, J. R. O. (2009). Características sensoriais da carne de cordeiros da raça Santa Inês submetidos a diferentes dietas. *Ciência e Agrotecnologia*, *33*(1), 185-190. doi: 10.1590/S1413-70542009000100026

Gao, X., Wang, Z., Mião, J., Xie, L., Dai, Y., Li, X.,... Dai, R. (2014). Influence of different production strategies on the stability of color, oxygen consumption and metmyoglobin reducing activity of meat from Ningxia Tan sheep. *Meat Science, 96*(2), 769-774. doi: 10.1016/j.meatsci.2013.09.026

Guerrero, A., Valero, M. V., Campo, M. M., & Sañudo, C. (2013). Some factors that affect ruminant meat quality: from the farm to the fork. Review. *Acta Science Animal Science*, *35*(4), 335-347. doi: 10.4025/actascianimsci.v35i4.21756

Hamm, R. (1986). Functional propertie soft hemiofibrillar system and theirmeasurement. In P. J. Bechtel (Ed.), *Muscle as food* (pp. 135-199). Orlando: Academic Press.

Huidobro, F. R., Miguel, E., Blázquez, B., & Onega, E. (2005). Comparison between two methods (Warner–Bratzler and texture profile analysis) for testing either raw meat or cooked meat. *Meat Science, 69*(3), 527-536. doi: 10.1016/j.meatsci.2004.09.008

Kirton, A. H., Crane, B., Paterson, D. J., & Clare, N. T. (1975). Yellow fat in lambs caused by carotenoid pigmentation. *New Zealand Journal of Agricultural Research*, *18*(3), 267- 272. doi: 10.1080/00288233.1975.10423643

Macfie, H. J., Bratchell, N., Greenhoff, K., & Vallis, L. (1989). Designs to balance the effect of order presentation and first-order effects in hall tests. *Journal of Sensory Studies, 4*(2), 129-148. doi: 10.1111/j.1745-459X.1989.tb00463.x

National Research Council (2007). *Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids.* Washington, D.C.: National Academy Press.

Osório, J. C. S., Osório, M. T. M., & Sañudo, C. (2009). Características sensoriais da carne ovina. *Revista Brasileira de Zootecnia, 38*(Esp.), 292-300. doi: 10.1590/S1516-35982009001300029

Osório, J. C., Osório, M. T. M., & Jardim, P. O. (1998). *Métodos para avaliação da produção de carne ovina: "in vivo" na carcaça e na carne.* Pelotas: UFPEL.

Pinheiro, R. S. B., Silva Sobrinho, A. G., Souza, H. B. A., & Yamamoto, S. M. (2009). Qualidade de carnes provenientes de cortes da carcaça de cordeiros e de ovinos adultos. *Revista Brasileira de Zootecnia*, *38*(9), 1790-1796. doi: 10.1590/S1516-35982009000900022

Rocha, V. R. R. A., Dutra, W. M., Jr., Rabello, C. B. V., Ramalho, R. P., Ludke, M. C. M. M., & Silva, E. C. (2008). Substituição total do milho por sorgo e óleo de abatedouro avícola em dietas para frangos de corte. *Revista Brasileira de Zootecnia*, *37*(1), 95-102. doi: 10.1590/S1516-35982008000100014

Rota, E. L., Osório, M. T. M., Osório, J. C. S., Oliveira, M. M., Wiegand, M. M., Mendonça, G.,... Gonçalves, M. (2006). Influência da castração e da idade de abate sobre as características subjetivas e instrumentais da carne de cordeiros Corriedale. *Revista Brasileira de Zootecnia*, *35*(6),2397-2405. doi: 10.1590/S1516-35982006000800028

Rubiano, G. A. G., Arrigoni, M. B., Martins, C. L., Rodrigues, E., Gonçalves, C., & Angerami, C. N. (2009). Desempenho, características de carcaça e qualidade da carne de bovinos superprecoces das raças Canchim, Nelore e seus mestiços. *Revista Brasileira de Zootecnia*, *38*(12), 2490-2498. doi: 10.1590/S1516-35982009001200027

Statistical Analysis System Institute (2014). *Statistical analysis systems user's guide.* Cary, NC: SAS Institute.

Silva Sobrinho, A. G., Purchas, R. W., Kadim, I. T. K., & Yamamoto, S. M. (2005). Características de qualidade da carne de ovinos de diferentes genótipos e idades ao abate. *Revista Brasileira de Zootecnia*, *34*(3), 1070-1078. doi: 10.1590/S1516-35982005000300040

Venturini, R. S., Carvalho, S., Pires, C. C., Pacheco, P. S., Pellegrin, A. C. R. S., Moro, A. B.,... Motta, J. H. (2016). Consumo e desempenho de cordeiros e borregos alimentados com dietas de alto concentrado de milho ou sorgo. *Arquivos Brasileiro de Medicina Veterinária e Zootecnia, 68(*6), 1638-1646. doi: 10.1590/1678-4162-8856

Zeola, N. M. B. L., Souza, P. A., Souza, H. B. A., Silva Sobrinho, A. G., & Barbosa, J. C. (2007). Cor, capacidade de retenção de água e maciez da carne de cordeiro maturada e injetada com cloreto de cálcio. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 59*(4), 1058-1066. doi: 10.1590/S0102-09352007000400036