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Physicochemical and microbiological meat quality, growth performance and carcass characteristics of feedlot-finished cull Santa Inês ewes and Moxotó goats[1]

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This study aimed at assessing the physicochemical and microbiological quality of feedlot-finished, culled Santa Inês ewes and Moxotó goats, and compares the intake, weight gain and carcass characteristics. Three Santa Inês ewes and Moxotó goats with similar ages were confined in double and/or individual pens and then euthanized after 40 days of confinement. The average intake, daily weight gain, hot carcass yield, cold carcass yield, weight loss by cooling and rib eye area (94.45%, 0.220 kg/day, 41.37%, 40.14%, 2.99%, 16.1 cm², respectively) of the Santa Inês ewes were higher than that of the Moxotó goats (84.01%; 0.06 kg/day; 41.55%; 39.81%; 4.12%; and 11.35 cm², respectively). The chevon (goat meat) showed higher protein levels (23.09 g/100 g), lower lipid levels (1.43 g/100 g) and higher red-color intensity (11.62), although it had lower tenderness (8.98 kgf shear strength). The superiority of the culled ewes was assessed relative to that of the culled goats, and the results showed that the Santa Inês sheep has better performance than the Moxotó goats. However, mutton and chevon derived from the culled animals are promising alternatives for small farmers because culled meats add value to the standard meat obtained from these animals, broaden sales alternatives and increase profitability.

Key words: Performance parameters, physicochemical parameters, microbiological parameters, cull animals.

INTRODUCTION

The search for healthier foods has influence changes in eating habits of meat consumer in recent years. The interest in mutton (sheep meat) and chevon (goat meat) has grown substantially, partially because of the increased interest in their possible beneficial effects on consumer health, which is related to their characteristics as natural resources with high-quality protein production (Carvalho et al., 2007) and lower levels of cholesterol, saturated fat and calories than other red meats (Madruga, 2004). Goat meat is considered a lean meat and its chemical composition is in agreement with current consumer requirements. On the other hand, sheep meat is smoother and juicier (Costa et al., 2008).

Culling is a common practice in farms with full production cycles, and the sale of culled animals is often complicated by low acceptability of the meat by the

Table 1. Bromatological composition of the concentrate feed and corn silage provided to Santa Inês ewes and Moxotó goats.

Parameter	Diet	
	Concentrate feed	Corn silage
DM (%)	93.1	30.0
MM (%)	6.39	3.33
CP (%)	15.92	5.55
NDF (%)	32.58	63.63
ADF (%)	15.74	27.95
TDN (%)	83.05	61.93

DM, dry matter; MM, mineral matter; CP, crude protein; NDF, neutral-detergent insoluble fiber; ADF, acid-detergent insoluble fiber; TDN, total digestible nutrients.

consumer market (Pelegrini et al., 2008). Culled meat is difficult to sell because fat accumulation increases in the carcass with age (François, 2009). Fat has the greatest variability among animal tissue, both quantitatively and with regard to its distribution (Pelegrini et al., 2008). The composition of fatty acids in lipids directly affects the nutritional and sensory qualities of the meat, and greater saturation reduces quality, especially considering its negative effects to human health (Mahgoub et al., 2002).

Confinement is an alternative for consideration among production systems because it promotes higher weight gain and better quality carcasses (Hashimoto et al., 2007). Neres et al. (2001) indicated that good productivity and medium-sized ruminant carcass quality are difficult to achieve on native pasture systems primarily because of nutrient deficiencies; thus, the use of cultivated pastures and supplementation in grazing and/or confinement are required to fully exploit the genetic potential of animals.

Thus, this study aimed at checking the composition of meat of different species assessing the physicochemical and microbiological quality of sheep and goat meat and compares the intake, weight gain and carcass characteristics of feedlot-finished, culled Santa Inês ewes and Moxotó goats.

MATERIALS AND METHODS

This research project was submitted to the Research Ethics Committee (Comitê de Ética em Pesquisa, CEP) of the Federal Institute of Education, Science and Technology of Goiás (Instituto Federal de Educação, Ciência e Tecnologia Goiano) and is in compliance with the National Health Council (Conselho Nacional de Saúde, CNS) Resolution 196/96, and it received an approval protocol (No. 022/2013) prior to conducting the experiment.

The experiment was conducted from October to December 2013 at the Sheep Farming Center of the Department of Animal Science of the Federal Institute of Goiás (Instituto Federal Goiano), Rio Verde Campus, Goiás (GO), which is located in southwest GO at 17° 47’ 53” S, 51° 55’ 53” W and 815 m average altitude.

The animals were confined for a 40-day period, and the first 10 days were used for adaptation to the facilities and experimental diet. Three Santa Inês ewes and three Moxotó goats of similar ages (full mouth with visible wear of incisors) were used, and the animals were previously tagged, wormed and randomly distributed in confinement systems according to the animal species (goat and sheep). The animals were housed in 1.20 × 2.10 m (2.52 m^2) roofed pens with concrete floors, and the pens were equipped with feeders and drinkers that were cleaned every two days. The feces were collected daily and disposed in a compost bin.

The diet provided to the confined animals consisted of 50% corn silage and 50% concentrate feed, and it was supplied twice daily at 8 AM and 6 PM. The roughage and concentrate were weighed on an electronic scale accurate to 5 g and mixed when supplying the feed. The amount supplied was adjusted according to the leftovers, which were collected and weighed and should have been a maximum of 10% of the amount supplied. Water was supplied ad libitum.

The concentrate feed used in the animal diet was purchased from a local shop in Rio Verde – GO, and the corn-based roughage feed (silage) was produced at the Federal Institute of Goiás (Instituto Federal Goiano), Rio Verde Campus.

Samples of the feed and silage were ground in a Wiley mill, sieved through 1 mm mesh and placed in a convection oven at 105°C for approximately 12 h to determine the dry matter (DM) content according to the method of Silva and Queiroz (2002), incinerated in a muffle furnace at 600°C to determine the mineral matter (MM), treated with the semi-micro-Kjeldahl method to determine the crude protein (CP), and assessed using the Filter Bag Technique in a fiber measuring device (model TE-149 – Tecnal®) to determine the neutral detergent fiber (NDF) and acid detergent fiber (ADF) content according to the method of Van Soest et al. (1994). The silage and concentrate bromatological compositions are outlined in Table 1.

The average daily intake per animal was assessed by calculating the difference between the amount of feed supplied and rejected (leftovers). The animals were weighed at the start of confinement (initial weight, IW) and prior to slaughter (slaughter weight, SW). Intermediate weighing assessments between IW and SW were performed regularly every seven days to monitor performance. All weighing assessments were performed in the morning after fasting of solids for 14 h. The total weight gain (TWG) was assessed by calculating the difference between the SW and IW, and the daily weight gain (DWG) was assessed by calculating the difference between two weighing and dividing that figure by the number of days between weighing assessments.

The ewes and goats were subjected to 16 h water diets and weighed again prior to slaughter, and the live weight at slaughter (LWS) was calculated at day 40. The slaughter was conducted at

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Abbreviations: CV, coefficient of variation; **ADI,** average daily intake; **TWG,** total weight gain; **DWG,** daily weight gain; **HCY,** hot carcass yield; **CCY,** cold carcass yield; **WLC,** weight loss by cooling; **REA,** rib eye area; **DM,** dry matter; **MM,** mineral matter; **CP,** crude protein; **NDF,** neutral-detergent insoluble fiber; **ADF,** acid-detergent insoluble fiber; **TDN,** total digestible nutrients.

Table 2. Mean values for the intake, weight gain, hot and cold carcass yield, weight loss by cooling and rib eye area of the culled Santa Inês ewes and Moxotó goats.

Parameter	Mean[(1)]	SD	CV (%)	Mean[(1)]	SD	CV (%)
	Ewes			Goats		
ADI (%)	94.45	± 2.08	1.2	84.01	± 1.43	0.82
TWG (kg)	8.73	± 4.10	2.37	2.47	± 1.19	0.48
DWG (kg)	0.22	± 0.10	0.06	0.06	± 0.03	0.02
HCY (%)	41.37	± 0.14	0.08	41.55	± 3.97	0.10
CCY (%)	40.14	± 0.41	0.24	39.81	± 3.34	1.93
WLC (%)	2.99	± 1.12	0.65	4.12	± 1.16	0.67
REA (cm²)	16.1	± 3.20	1.85	11.35	± 2.68	2.68

[(1)]Means from the analyses. SD, standard deviation; CV, coefficient of variation; ADI, average daily intake; TWG, total weight gain; DWG, daily weight gain; HCY, hot carcass yield; CCY, cold carcass yield; WLC, weight loss by cooling; REA, rib eye area.

the municipal slaughterhouse of the city of Rio Verde, GO and supervised by the Municipal Inspection Service (Serviço de Inspeção Municipal), using the humane slaughter method. The following samples were collected from the slaughtered animals: blood, skin, guts, internal organs, feet (severed at the level of the tarsal-metatarsal and carpal-metacarpal joints) and head (severed at the level of the atlantooccipital joint). The remainder of the animal's body was identified and weighed to assess the hot carcass weight (HCW) and hot carcass yield (HCY).

The HCY was assessed using the equation below:

$$HCY\ (\%) = \frac{HCW}{SW} * 100$$

HCY (%) = hot carcass yield expressed as percentage; HCW = hot carcass weight (kg); SW = final fasting weight or slaughter weight (kg).

The hot carcass was transported to the cold room suspended by the joints on overhead rails and kept 17 cm apart from the other carcass; the carcasses were maintained at a temperature of 2°C for a 24 h period and then weighed again to assess the cold carcass weight (CCW).

The cold carcass yield (CCY) was calculated after assessing the CCW as follows:

$$CCY\ (\%) = \frac{CCY}{SW} * 100$$

Where, CCY (%) = cold carcass yield expressed as percentage; CCW = cold carcass weight (kg); SW = final fasting weight or slaughter weight (kg).

The weight loss by cooling was assessed using the following equation:

$$WLC\ (\%) = \frac{(HCW\ -\ CCW)}{HCW} * 100$$

Where, WLC (%) = weight loss by cooling expressed as percentage; HCW = hot carcass weight (kg); CCW = cold carcass weight (kg).

A cross-section of the *Longissimus dorsi* muscle was performed between the 12^{th} and 13^{th} ribs to assess the rib eye area (REA) according to the method of Osório et al. (1998), and color, shear strength and microbiological analyses were performed to determine the protein, lipid, moisture, ash and pH levels according to the Association of Official Agricultural Chemists (AOAC, 2000). All of the analyses were performed in triplicate.

The color analysis was performed using a Hunter Lab Colorimeter, model Color Quest II, and the values were expressed as L*, a* and b*, where L* (luminosity or brightness) may range from black (0) to white (100), a* (chroma) may range from green (-60) to red (+60) and b* (chroma) may range from blue (-60) to yellow (+60) as reported by Paucar-Menacho et al. (2008).

The shear strength was assessed using a Stable Micro Systems® texturometer model TAXT, in addition to a texture analyzer with blade set that included a knife (blade and guillotine), which was applied at a temperature of 25°C. Samples of 2.0 cm diameter and 1 cm mean height were used for this analysis. The pre-test speed was 10 mm/s, test speed was 5 mm/s and post-test speed was 10 mm/s.

Microbiological analyses were performed in mutton and chevon using the most probable number (MPN) method to count the total coliforms and fecal coliforms. The MPN is a classic culture method to assess *Salmonella* and analyze *Staphylococcus aureus* by performing direct counts in plates according to the method recommended by Silva and Junqueira (2001).

The data on the performance and carcass characteristics were analyzed using a descriptive statistical analysis (Borba, 2014), and the results from the physicochemical analysis were assessed through a completely randomized design (CRD). Three replicates were performed in triplicate for all analyses using the Software Sisvar (Ferreira, 2003) at the 5% significance level according to Tukey's test.

RESULTS AND DISCUSSION

Performance and carcass characteristics

The culled Santa Inês ewes showed a 94.45% average daily intake, 0.220 kg/day daily weight gain, 41.37% hot carcass yield, 40.14% CCY, 2.99% weight loss by cooling and 16.1 cm² rib eye area (Table 2) after the 40 experimental days. The culled Moxotó goats showed an 84.01% average daily intake, 0.06 kg/day daily weight gain, 41.55% hot carcass yield, 39.81% CCY, 4.12% weight loss by cooling and 11.35 cm² rib eye area (Table 2).

Superiority of the culled ewes over the culled goats was observed in all of the evaluated parameters, indicating. that Santa Inês sheep have better performance than Moxotó goats (Table 2).

Table 3. Physicochemical results for the culled Santa Inês mutton and Moxotó chevon.

Parameter	Mutton	Chevon	CV (%)	F Value
Protein (g/100 g)	20.38 ± 1.9^B	23.09 ± 1.6^A	8.22	10.40*
Lipids (g/100 g)	2.65 ± 0.99^A	1.43 ± 0.35^B	12.06	36.33*
Moisture (g/100 g)	70.65 ± 1.8^B	74.11 ± 1.2^A	2.13	22.74*
Ash (g/100 g)	0.96 ± 0.03^B	0.92 ± 0.02^A	2.67	11.62*
pH	5.94 ± 0.10^B	6.06 ± 0.08^A	1.53	7.11*
L	41.31 ± 4.95^A	43.53 ± 2.21^A	9.04	4.03^{ns}
a*	9.69 ± 0.86^B	11.62 ± 1.11^A	9.3	45.4*
b*	7.26 ± 0.82^B	10.22 ± 1.35^A	12.8	84.3*
Shear (kgf)	4.74 ± 3.96^B	8.98 ± 3.34^A	53.4	7.4*

Different letters in the same row indicate significant differences (P<0.01) according to Tukey's test. *Significant at the 5% probability level. ^{ns}Not significant.

François (2009) obtained lower values than those indicated here and reported that culled ewes presented a 0,140 kg/day weight gain over 75 days, and Brum et al. (2008) also obtained lower results, reporting 0.151 kg/day daily weight gain when evaluating Corriedale ewe lambs maintained on cultivated millet pasture with 10% supply; the differences in the study results are attributed to the different diets provided. The average daily weight gain values recorded in this experiment were close to the values reported by Dantas et al. (2008), who studied the carcass characteristics of pasture-finished Santa Inês sheep submitted to different levels of supplementation and found that the supplemented animals showed a daily weight gain of 192 and 148 g.

Similar weight gain results to those of the Moxotó goats highlighted in the present study were reported by Menezes et al. (2004), who examined the intake of goats when corn was replaced by cassava peel and indicated that the average daily weight gain of the animals was unsatisfactory, even for the treatment without cassava peel (0.098 kg/day). Similar weight gains were also reported by Bueno et al. (2000), who observed 0.058 kg/day weight gain in growing goats fed a diet of dried citrus pulp as a replacement for corn.

The HCY and CCY observed in this experiment were close to those assessed by Pelegrini (2007), who observed 47.25 and 45.20% HCY in Texel and Ideal ewes, respectively, and 43.72% and 45.95% CCY for Texel and Ideal ewes, respectively. The higher HCY and CCY of the ewes was a result of their greater SW.

Bernardo et al. (2008) reported 45.60%, 45.86% and 43.34% HCYs and 44.73%, 44.96% and 42.34% CCYs when studying the carcass characteristics of Anglo-Nubian, Boer and mongrel crossbred goats, respectively, which is consistent with the results of this study.

The results presented here are important because they show that the performance of culled ewes and goats would not preclude their commercial viability because they showed similar DWG values to those reported in the literature.

Meat characteristics

The protein levels ranged from 20.38 to 23.09 g/100 g for mutton and chevon, as shown in Table 3. Chevon showed higher protein values (23.09 g/100 g) that were significantly different (p≤0.05) from those of mutton (20.38 g/100 g).

The mean protein levels of the two meats were similar, although they may change with animal age at slaughter, with a trend towards increased protein with age (Oliveira, 2011). The higher protein levels of chevon are related to genetic factors and lower lipid levels.

A significant difference in lipid levels was observed between the species, with mutton showing higher values (2.65 g/100 g) and chevon showing lower values (1.43 g/100 g). Fat is a key factor for meat quality, and it directly affects the sensory properties and nutritional value. Fat is the most variable basic meat component, and it is directly affected by several factors, including species, breed, age, sex, nutrition and cut (Lawrie, 2005).

The meat moisture level of the different species was higher in chevon (74.11 g/100 g), and the value was significantly different (p<0.05) from that of mutton (70.65 g/100 g). The moisture levels are directly related to the fat levels, with higher fat levels corresponding to lower water levels. Mutton showed higher levels of inorganic residue (ash; 0.96 g/100 g) compared with that of chevon (0.92 g/100 g).

pH is associated with pre-slaughter and slaughter conditions, animal excitability, muscle glycolytic potential and carcass cooling temperature (Lima, 2009). The final muscle pH also varies according to animal species and muscle type. The pH values may range from 5.5 to 5.8 in muscles with predominantly fast-twitch fibers (white fibers), whereas values ranging from 5.8 to 6.4 are observed in slow twitch muscles (red fibers). The pH values were similar between the different species, although there were slight differences (mutton 5.94; and chevon 6.06).

The final muscle pH is a factor that affects several meat

Table 4. Results from the microbiological analyses of culled Santa Inês mutton and Moxotó chevon.

Microorganism	Mutton	Chevon
Total coliforms (log_{10})	4.38	4.38
Thermotolerant coliforms (log_{10})	4.38	4.38
Salmonella	abs.	abs.
S. aureus	abs.	abs.

quality aspects, including the water holding capacity, cooking weight loss, shear strength, tenderness, juiciness and color (Lawrie, 2005). The meat chemical composition of the different species showed similar values to those reported in the literature, and this finding corroborates Beserra et al. (2000), who recorded values ranging from 15.9 g/100 g to 19.08 g/100 g for protein levels; 77.80 g/100 g to 80.25 g/100 g for moisture levels; 1.12 g/100 g to 1.21 g/100 g for fat levels; and 1.29 g/100 g to 2.03 g/100 g for ash levels in a study of the chemical characteristics of cabrito from the Moxotó breed and Alpine brown x Moxotó cross-bred animals.

Similar values to those presented here were reported by Dias et al. (2002), who recorded 76.54 g/100 g, 1.08 g/100 g, 2.06 g/100 g and 23.27 g/100 g for moisture, ash, lipid and protein levels, respectively, when examining the physical and physicochemical characteristics of culled Moxotó chevon, as well as those reported by Duarte (2003), who recorded values of 75.13 g/100 g, 22.69 g/100 g, 2.55 g/100 g and 0.98 g/100 g for moisture, protein, fat and ash levels, respectively, when analyzing shoulder cuts from crossbred Boer goats slaughtered at 228 days.

Pinheiro et al. (2008) found values of 74.05 g/100 g moisture, 5.36 g/100 g fat, 18.85 g/100 g proteins and 1.15 g/100 g ash in a study of the chemical composition and yield of mutton *in natura*, which is consistent with the results shown for the meat physicochemical characteristics. Different values were reported by Santos Júnior et al. (2009), who recorded values of 76 g/100 g moisture, 19.18 g/100 g protein, 5.40 g/100 g lipids, 1.18 g/100 g ash and 5.56 pH in a study of the physicochemical characteristics of culled mutton used to prepare hamburgers supplemented with oat flour.

The meats from different species mostly showed dark (intermediate values of L*), red (positive component a*) and yellowish (positive component b*) coloration. Chevon showed values of 43.53 L*, 11.62 a* and 10.22 b*, with similar values to mutton for L*(41.41) and different values for a* (9.69) and b* (7.26). Chevon is noticeably similar to mutton in color despite showing higher L* values; however, its color is a brighter brick-red color (11.62 a*) compared with that of mutton (9.69).

The meat color is dependent on its total myoglobin content and is affected by the species, sex, age, nutrition and slaughter conditions. Similar culled mutton results to those presented here were reported by Santos Júnior et al. (2009), who assessed values of 39.75; 13.08 and 11.78 for the parameters L*, a* and b*, respectively. Lower L*, red and yellow parameters were reported by Sobrinho et al. (2005) when assessing the mutton quality characteristics of different genotypes and different ages at slaughter; these authors found L* values ranging from 37.26 to 37.91, a* values ranging from 7.71 to 7.91 and b* values ranging from 4.19 to 4.39. The mutton red (a*) levels were lower than those reported by Esteves (2011), who identified the color of mutton at different ages and observed values of 36.37 L*, 16.74 a* and 7.34 b*.

Dias et al. (2002) reported different L* (24.98) and yellow intensity (1.24) in the color analysis of culled chevon from the Moxotó breed, although similar red intensity values (15.29) were observed and confirmed the intense color of the meat.

The shear strength value (Table 3) of mutton was 4.74 kgf and chevon was 8.98 kgf. Thus, chevon showed a higher value from that of mutton. Genetics, breed, slaughter age, sex, nutrition, muscle fiber bundle size, connective tissue, contracted muscle fibers post-mortem and meat lipid levels stand out among the factors affecting meat tenderness (ALVES et al., 2005).

Pinheiro et al. (2009) and Zeola et al. (2005) recorded mean values of shear strength from 2.35 kgf to 4.08 kgf and 4 kgf in a study of Santa Inês sheep at different physiological stages and culled ½ Ile de France x ½ Ideal crossbred ewes, and these values corroborate the shear strength results assessed in this study.

Conversely, Dias et al. (2002) found a lower shear strength value of 4.97 kgf for chevon from culled animals, which were related to the higher fat levels.

The microbiological analysis of the meats showed an absence of *Salmonella* and *S. aureus*. However, the analysis of total and thermotolerant coliforms showed a count of 4.38 log_{10} for both microorganisms (Table 4). The total coliform value indicates contamination during the slaughter process and deficient handling, cleaning and sanitation. Thermotolerant coliforms indicate fecal contamination because that group originates exclusively from the intestinal tracts of warm-blooded animals.

Resolution 12 (RDC12) of the National Health Surveillance Agency (Agência Nacional de Vigilância Sanitária; Brasil, 2001) defines the technical regulations related to the microbiological standards for food, including beef, pork and other mammal meats that are refrigerated or frozen "*in natura*" (whole or cut carcasses, quarters or cuts). The 25 g samples of ground meats and viscera from cattle, pigs and other mammals did not include *Salmonella*. However, the values shown meet the standards required by the current legislation.

Conclusion

The results indicate that culled Santa Inês ewes have a better intake, weight gain and carcass yield than culled Moxotó goats. Chevon showed higher protein levels, lower lipid levels and higher red color intensity, although it also had lower tenderness. The microbiological quality of the meat indicated contamination during the slaughter process and deficient handling, cleaning and sanitation. Chevon and mutton derived from culled animals is a promising alternative for small farmers because culled meats add value to the standard meat obtained from these animals, broaden sales alternatives and increase profitability.

Conflict of interests

The authors did not declare any conflict of interest.

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