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Do carcasses of lambs finished on commercial production systems meet market standards?

RAIMUNDO N.B. LÔBO[1,2], ANDRÉS CHAPARRO-PINZÓN[1], FRANCISCO V.O. MELO NETO[1], LISIANE D. LIMA[2], ANA SANCHA M. BATISTA[3] and ANA MARIA B.O. LÔBO[2]

[1]Departamento de Zootecnia, Universidade Federal do Ceará, Avenida Mister Hull, s/n, Antônio Bezerra, 60455-760 Fortaleza, CE, Brazil
[2]Embrapa Caprinos e Ovinos, Fazenda Três Lagoas, Estrada Sobral/Groaíras, Km 4, Caixa Postal 71, 62010-970 Sobral, CE, Brazil
[3]Coordenação de Zootecnia, Universidade Estadual Vale do Acaraú/UVA, Avenida da Universidade, 850, Campus da Betânia, 62040-370 Sobral, CE, Brazil

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ABSTRACT

This study aimed to characterize a commercial lamb finishing system using animals of undefined breed from production to slaughter by analyzing performance, carcass traits, yield of commercial cuts, and the quality and meat acceptance of different slaughter groups, as to evaluate whether this system provides the market with a standardized product. The lots were not homogeneous for yield of commercial cuts and performance and morphometric traits evaluated *in vivo*. The groups were heterogeneous to 75% of the 13 carcass traits evaluated, among them, hot and cold carcass weights, hot and cold carcass yields, carcass grade finishing and biological yield. There was also no uniformity for the proportion of non-carcass components, morphometry of carcass, visual appraisals, and loin traits. On the other hand, homogeneity was achieved in physico-chemical and sensory traits, except for hardness and proportion of saturated, monounsaturated and polyunsaturated fatty acids. We conclude that the commercial finishing system with the use of undefined crossbred lambs does not produce carcass and cuts standardized to the market.

Key words: carcass morphology, carcass yields, fatty acid, sensory analysis, slaughter weight.

INTRODUCTION

The commercial production of meat sheep in many developing regions, especially in the Brazilian Northeast, is characterized by the use of animals of undefined breed, derived from the crossbreeding of local with transboundary breeds and raised in several different production systems. This type of system contributes to a variety of results and the challenges that are commonly cited for this activity are reduced growth rate, late slaughters with carcasses of varying weight, low yield, and quality different from that required by the market (Lôbo 2002), as well as a seasonal availability. Thus, this industry is characterized by being multifunctional and traditionally exploited with low use of specialized technologies (Simplício et al. 2004).

Among the recommended approaches to meet these challenges, Lôbo et al. (2012) mentions the use of genetic resources suitable to the production

Correspondence to: Raimundo Nonato Braga Lôbo
E-mail: raimundo.lobo@embrapa.br

system and the finishing of lambs in confinement soon after the weaning, thus eliminating the reared phase (Lima et al. 2013). The latter practice has been recommended by providing early slaughter lambs, with carcasses and skin having a better quality. Another important aspect is that it can enable regular supply for the consumer market, even in the period of low forage production, generating a better economic return. However, it is vital that these technologies are in tune with one another in a way that the results can be satisfactory since there is no point in confining animals that do not have potential to respond to the cost/benefit of this management.

Several studies have evaluated the performance of animals in confinement at research institutions, under experimental conditions, and considering various treatments (Kocak et al. 2015, Hajji et al. 2016). The results on commercial terms under general management observed in most farms, however, are not clear. Thus, the main purpose of this study was to characterize the production of lamb meat on a commercial system, considering the use of slaughtered undefined crossbred animals, under feedlot, after the reared phase had occurred with their dams on pasture. Additionally, we evaluated the standardization of the product offered to the market in four production cycles.

MATERIALS AND METHODS

This study complied with the norms of the Committee of Ethics for Animal Use (CEUA) from Federal University of Ceará. The evaluated animals were from a commercial production system of the Guaiúba Farm and Slaughterhouse, located at 4°03'19.4"S and 38°37'16.9"W in the municipality of Guaiúba, CE, Brazil. It is important to highlight that no intervention in the management and slaughter procedures of the animals took place during this study.

The flock was composed by crossbred ewes, with unknown genetic composition (undefined breed animals), mated randomly with Santa Inês, Dorper and Brazilian Somali rams. Slaughter's groups were constituted from subsequent breeding seasons. However, in the farm represented in our study, the slaughter groups did not correspond exactly to the same groups of finishing, i.e., in each slaughter group could have lambs of distinct groups of finishing. According to the farm's criteria, the slaughter groups were composed by lambs with body weight close to 30kg. Therefore, periodically and according to the market demand, the manager surveyed the groups of finishing and selected the lambs which he visually judged to have 30kg of weight. The ewes were raised on pasture and gathered in the late afternoon to supplementation with commercial concentrate ration (about 300g/day/ewe). Before weaning, the lambs followed the ewes' management on pasture and in the stalls in the late afternoon. They had access to commercial ration for growing, based on soy and corn. After weaning, between 70 and 90 days of age, male lambs were brought for finishing in confinement area and the females lambs brought to the replacement sector.

Four groups of finishing non-castrated lambs in confinement were evaluated, with an average of 68 days from each other. The number of lambs in each group was 40, 28, 42 and 50 lambs, respectively. Before the beginning of the finishing, the lambs were vaccinated for clostridiose and dewormed with levamisole hydrochloride 7.5%. Fifteen days after the beginning of the finishing, new deworming was performed using ivermectina 1%. The lambs were identified with tags, weighed and gathered in collective stalls with capacity for 50 individuals. The stalls were limited by smooth welded wire fabric, with covered area for ceramic tile, cement floor and large solarium of beaten ground, with slope for easy cleaning and disposal

of waste and water, they were also provided with feeders, drinkers and salt shaker.

The lambs were fed in the trough with chopped elephant grass (*Pennisetum purpureum*) with 3.76% of crude protein and concentrate ration (20% crude protein), with roughage/concentrate ration of 90:10. The diet was provided daily in three meals (8h30min, 13h30min and 16h30min), allowing orts of 10% on as - fed basis.

The lambs were weighed at the beginning of confinement to evaluate the initial and final weight and weight gain during the finishing. Following the farm's criteria, four slaughter groups were evaluated. The first (n = 30; average of 122 days of confinement) and second (n = 38; average of 189 days of confinement) groups had lambs from the first and second group of finishing, the third group (n = 32; average of 108 days in confinement) only animals from the third group of finishing and the fourth slaughter group (n = 42; average of 123 days of confinement) lambs of the third and fourth groups of finishing. The ranges of age of the lambs in the four slaughter groups were 192 to 212 days, 259 to 279 days, 178 to 198 days and 193 to 213 days, respectively.

One day before the slaughter, the lambs were weighed and traits such as thorax perimeter, leg perimeter, scrotal perimeter, height withers, height croup, thorax depth, length of croup, body length, chest width, croup width and corporal score (1-5), were measured.

The lambs were slaughtered in the slaughterhouse of the farm which had registry in the State Inspection Service of Agricultural Protection Agency of the State of Ceará (SIE/ADAGRI), in such a way that all slaughter procedures were performed according to inspection standards of that State.

The lambs were subjected to solid fasting and access to water 18 hours before slaughter. After the measurement of the slaughter weight (SW), the animals were desensitized with electrical discharge of 220V for 10 seconds and suspended by the hind legs, hereafter, the bleeding was performed with section of the carotid arteries and jugular veins. Blood was collected and weighed in order to determine the empty body weight. After bleeding and skinning, gastrointestinal content was withdrawn to determine the empty body weight (EBW), obtained from the difference between the SW and the gastrointestinal content. Soon after evisceration, the head and the distal part of the members were withdraw for obtaining the entire carcass. All non-carcass components were weighed to estimate their proportions. Without the skin, viscera, head, feet and genitals, the carcasses were weighed to determine the hot carcass weight (HCW). Based on this information and as according to Silva Sobrinho (2001), we calculated the hot carcass yield (HCY = (HCW / SW) × 100) and the biological or true yield (BY = (HCW / EWB) × 100). The carcasses were stored in cold chamber at 4° C for a period of 24 hours. After this period they were weighed to obtain the cold carcass weight (CCW), the cold carcass yield (CCY = (CCW / SW) × 100) and loss by cooling (LC = (HCW – CCW) / HCW × 100).

Temperature and pH was measured both in hot and cold carcass, with a portable pH meter with penetration electrode (model MD20, Digmed). For the insertion of the electrode was made a cut between the biceps femoral and semitendinosus. After each procedure, for each animal, electrode cleaning was performed using distilled water. The pH meter was calibrated with a buffer solution every five measurements.

After cooling, the carcasses were suspended by the hock and with the parallel legs, measurements of thorax perimeter, external carcass length, croup perimeter, leg perimeter, leg length and carcass depth were held. Visual appraisals of conformation and finishing of the carcass and content of pelvic-renal fat also were made, according to the method of Cezar and Sousa (2007), using a rating scale of

1 to 5. The evaluation of the carcass conformation was performed by observing the anatomical regions of the leg, rump, loin, shoulder and their muscle plans. The carcass finishing was evaluated with emphasis on the thickness and distribution of fat planes with respect to the skeleton.

Subsequently, the carcasses were cut in commercial courts, following the marketing standards of the Guaiúba Slaughterhouse: anterior and posterior loin, leg, neck, shoulder, rib and breast. After this, each cut, as well as the kidneys and the renal fat, were properly weighed for estimating their yields.

Visual appraisals of marbling, texture and color of the meat and texture and distribution of fat were performed in the Longissimus dorsi muscle (loin) according to subjective score described by Cezar and Sousa (2007). By using a Vernier caliper, it was also determined the rib eye area measurements (REA = (A / 2 × B / 2) × π) for obtaining the maximum width (A) and the maximum depth (B), and the backfat depth.

Ten samples of Longissimus dorsi of each slaughter group were collected for carrying out physical-chemical and sensory analysis. The samples were randomly selected from the design of blocks that considered the live weight of slaughter of animals in order to obtain samples of the heavier, intermediate and lighter lambs. Prior to evaluation, the samples were placed into polyethylene bags, frozen and stored at -20°C for up to 2 months. Moisture was determined by air-drying (AOAC 1984; procedure 24.002) and ash was determined according to AOAC (1984, procedure 24.009). The micro-Kjeldahl procedure (AOAC 1984; procedure 24.038) was used to determine the percentage of nitrogen, using a conversion factor of 6.25 to convert nitrogen to percentage protein.

The loss of weight due to cooking was determined according to Duckett et al. (1998b). The samples, composed of three slices of approximately 1.5 cm of thickness, 3.0 cm long and 2.5 cm wide, were weighed, covered with aluminum paper, and then cooked in a 170 °C pre-heated oven, until the temperature of the geometric center reached 71 °C. The samples were cooled to room temperature and weighed again. Losses due to cooking were calculated by the difference in weight before and after cooking, and expressed as percentage (g/100 g).

The water holding capacity was measured with a modified Grau and Hamm technique (Sierra 1973). A 0.5 g sample was disposed between two acrylic sheets which were subjected to a force of 5.00 kg/cm^2 for a period of five minutes. After this time, the sample was removed and reweighed. It was calculated by the difference in weight before and after pressure, and expressed as percentage (g/100 g).

The texture analysis was done by assessing the shear force following the methodology described by Duckett et al. (1998a). The same samples after loss of weight due to cooking analysis were used here. These were arranged in a texturometer Taxt-PLUS (Surrey, England) equipped with a Warner Bratzler blade-type, cutting the muscle fibers across, 20 cm/min. The peak shear force was recorded in kgf/cm^2.

The lipids from samples were extracted using the methodology presented by Bligh and Dyer (1959). The fatty acids were transmethylated according to method described by Molkentin and Precht 2000. The fat extracted was dissolved in 1 mL of hexane and mixed with 20 mL sodium methylated solution (2 N in methanol) in a sample vial. The solution was shaken vigorously for 3 min (vortex mixer) and centrifuged for 1 min (35xg). After addition of 10 mg sodium sulphate monohydrate, the vial was recapped, mixed again for 2 min and centrifuged at same speed for 1 min. The clear supernatant was used for gas chromatography analysis.

The fatty acid profile was determined by gas chromatography according to model modified from Chilliard et al. 2006, under the following conditions:

Column: SP 2560 (100mx0.25 mm x0.25 mm) - Supelco; Patterns: Supelco 37 - Component FAME Mix (10,000 mg in CH2Cl2) - Supelco cat. 47885-U, linoleic conjugated acid methyl ester - SIGMA Cat. O5632; flow of gas, injection in the split mode (1:100), 1 mL of sample, carrier gas - hydrogen (30 mL/min), make up - 30 mL/min, synthetic air - 300 mL/min; temperature of injector and detector (FID) - 250 ºC; programming temperature of oven: initial temperature 50 ºC hold 3 min, rate 4 ºC/min to 150 ºC hold 1 min, rate 1 ºC/min to 170 ºC hold 1 min, rate 8 ºC/min to 220 ºC hold 30 min, total run 86.25 min. The fatty acid composition of intramuscular fat was expressed as amount of each individual fatty acid per total fatty acids present. The indices used to predict the activity of desaturase enzyme, ID = (C18:1n9c / (C18:0 + C18:1n9c)), ID1 = (C16:1 / (C16:0 + C16:1)) and ID2 = ((C18:1n9c + C16:1) / (C18:0 + C18:1n9c + C16:0 + C16:1)) were also evaluated. Desaturase index is based on the relationship between substrate and product for D9 desaturase.

To find out if slaughter groups presented homogenious carcasses and meat features, ANOVA was performed considering a model with the groups and the age of the lambs as covariable, with the least-squares means compared by Bonferroni test ($p < 0.05$). To meet the assumptions of ANOVA, some traits were analyzed after transformation: 1/kidneys, $(\text{anterior loin})^{-2.4}$, log10(shear force), $(\text{ashes})^{4.3}$, log10(saturated), $(\text{monounsaturated})^{4}$, log10(polyunsaturated), $(\text{ID}+1)^{15}$, $(\text{ID2}+1)^{15}$, log10(polyunsaturated/saturated), $(\text{monounsaturated/saturated})^{2.3}$, 1/(polyunsaturated/monounsaturated); 1/(C15:0+1), log10(c16:0), $(\text{C18:1n9c}+1)^{3.1}$, 1/(C18:2n6c), 1/(C18:3n6+1), $(\text{C18:3n3}+1)^{-4.8}$, 1/(C18:2c9t11+1), $(\text{C18:2t10c12}+1)^{-12}$, $1/(\text{C20:4n6}+1)$, $(\text{C22:1n9}+1)^{-12}$, $(\text{C24:1}+1)^{-3.5}$). All the analyses were performed using the SAS (SAS Institute, 1996) program.

RESULTS AND DISCUSSION

This study presents a portrait of the situation of production and slaughter of lambs prevailing in developing countries, whose sheep industry is operated in secondary form, with disorganized and incipient production chain, one of the examples being Brazil. In this study, the absence of intervention in the means of production of the system and the provision of the meat to commercialization depicts the reality present on a daily basis in this kind of market. The results found here represent the actual product offered to the consumers.

There were differences ($p < 0.05$) in the morphological traits of the lambs taken *in vivo* according to the slaughter group, except for height withers, height and length of croup and chest width (Table I). In general, the lambs of the group 4 tended to have the lowest measurements. The corporal score ranged from 2.50 to 3.15 which according to Cartaxo et al. (2008), indicates an adequate conformation for lambs slaughtering.

The use of animals of undefined breed was responsible for the higher variation and lack of standardization observed in the body measurements among the slaughter groups. As there was no mating control and consequently of the genetic composition of the lambs, it was not possible to identify the genetic groups that promoted these differences. Crossbreeding practiced on the flock, although not controlled, tend to rotational crossbreeding with more than two breeds. This type of crossbreeding has a high fluctuation in the additive genetic composition of the population between generations (Gregory and Cundiff 1980), with consequent change in the performance of the animals, which can explain the differences in the inter-group performance, since each group could be composed of different genetic groups.

Notwithstanding the similarity among the groups for the daily weight gain, the heterogeneity

TABLE I
Least-square means for *in vivo* body measurements of the commercial lambs raised in confinement according to slaughter group.

Trait	Least-square means ± standard error			
	Group 1 (n = 30)	Group 2 (n = 38)	Group 3 (n = 32)	Group 4 (n = 42)
Thorax perimeter (cm)	74.96±0.62a	73.19±0.87ab	72.33±0.69b	71.09±0.53b
Leg perimeter (cm)	34.44±0.38a	34.55±0.53a	31.45±0.42b	28.70±0.32c
Scrotal perimeter (cm)	26.93±0.38a	24.96±0.53b	25.97±0.42ab	25.42±0.32b
Height withers (cm)	63.01±0.54	62.19±0.76	62.11±0.60	61.95±0.46
Height croup (cm)	64.42±0.60	64.11±0.84	62.64±0.67	63.23±0.51
Thorax depth (cm)	26.98±0.27a	26.57±0.37ab	26.46±0.29ab	26.01±0.23b
Length of croup (cm)	19.36±0.28	18.35±0.39	19.86±0.31	18.99±0.24
Body length (cm)	64.79±0.65a	62.39±0.92ab	62.94±0.72ab	61.21±0.56b
Chest width (cm)	9.89±0.24	8.74±0.34	9.99±0.27	9.82±0.21
Croup width (cm)	16.40±0.16a	15.52±0.23b	16.24±0.18ab	15.82±0.14b
Corporal score (pts)	2.95±0.08ab	2.50±0.11c	3.15±0.09a	2.78±0.07bc

Averages with different letters differ by Bonferroni test ($p < 0.05$).

of the body weights in the beginning and in the final of the confinement promoted differences among the groups in weight at slaughter, hot and cold carcass weight, hot and cold carcass yields and biological yield (Table II). These traits are considered the most important in the slaughterhouse since they represent the ratio of the weight of carcass and the live weight. Fernandes Júnior et al. (2013) noted that weight at slaughter differs between groups even using purebred animals (finished on grazing system) and that the genotype explained 52.8% of the slaughter weight, and 44.37% and 43.8% of the hot and cold carcass weight, respectively. Therefore each breed has its own potential for growth and deposition of meat and fat. The values shown here are within the range reported in the literature for purebreds and crossbred in other finishing systems (Fernandes Júnior et al. 2013, Cunha et al. 2008). However, the focus of this work was to assess whether the slaughter groups randomly set by the breeder ensures homogeneity carcasses, cuts, yields, and quality. Regarding the hot and cold carcass weights the differences among groups represented approximately 2.5kg (the average difference between groups 4 and 1) and when concerning hot and cold carcass yields, the differences corresponded on average to 3.57% and 7.15% (the average difference between groups 4 and 3). For biological yield, these differences were more subtle and barely perceptible.

Among the traits of visual appraisal of the carcass, only the carcass finishing grade was different ($p < 0.05$) among the groups. Fernandes Júnior et al. (2013) reported average values of 2.73 pts, 1.86 pts, 1.58 pts and 2.50 pts for conformation grade for Santa Inês, Brazilian Somali, Morada Nova and ½Dorper x ½ Morada Nova, respectively, and 1.62 pts, 3.29 pts, 1.08 pts and 2.00 pts for finishing grade for the same groups, respectively. The conformation grade for Santa Inês was closer to those observed in this study. Currently, this is the main sheep breed in Brazil, and probably the main base of the flock studied here. The highest values for finishing grade observed here are justified when compared to the study of Fernandes Júnior et al. (2013), whose lambs were raised in pasture. Actually, there are genetic differences among the lambs distributed in the different slaughter groups that are impossible to identify in this study, mainly due to the lack of knowledge on previous matings. However, here we

present a solid example of what is common practice in commercial production systems of sheep meat. In addition to the effect of diet, the genotype has significant effect on the conformation, finishing and pelvic-renal fat of the lambs carcass (Cartaxo et al. 2011).

The loss during cooling is an important trait and is associated mainly with fat thickness and moisture loss in the carcass. It is an indicative of protection for housing during the residence time in the freezer. The homogeneity observed for this parameter showed that the groups produced similar subcutaneous fat amount which acted as insulation of the muscular mass. The losses by cooling reported are within the range for sheep in Brazil (Moura Neto et al. 2014, Fernandes Júnior et al. 2013).

Although there were differences among the groups for pH and hot and cold carcass temperatures, these parameters were within normal limits. The final pH is an important quality parameter due to its relationship with the color of the meat. Here, group 2 presented cold carcass pH above 6 and had the lowest score for meat color (3 = light red). Fernandes Júnior et al. (2013) reported pH values between 6.59 to 6.75 and 5.25 to 5.42 for cold and hot carcass respectively, in Santa Inês, Brazilian Somali, Morada Nova and F1 (½ Dorper × ½ Morada Nova) genetics groups.

INITIAL AND FINAL WEIGHT AND DAILY WEIGHT GAIN CORRESPONDS TO FINISHING PERIOD

There was no homogeneity between the slaughter groups in four morphometrics traits of the carcass among the six which were evaluated (Table III). This showed that the use of animals with undefined genetic groups creates a wide variation in the size of the carcass. This is the result of the characteristics of each breed used in the crossbreeding (Santa

TABLE II
Least-square means for traits of the commercial lambs raised in confinement according to slaughter group.

Trait	Least-square mean ± standard error			
	Group 1 (n = 30)	Group 2 (n = 38)	Group3 (n = 32)	Group 4 (n = 42)
Initial weight (kg)	21.99±0.58a	16.82±0.82c	21.45±0.65ab	19.89±0.50b
Final weight (kg)	35.94±0.77a	32.30±1.09ab	34.17±0.86ab	32.42±0.66b
Daily weight gain (kg/day)	0.104±0.004	0.117±0.006	0.094±0.005	0.097±0.004
Slaughter weight (kg)	33.76±0.81a	29.29±1.14b	28.08±0.90b	29.88±0.69b
Hot carcass weight (kg)	14.88±0.38a	13.20±0.53ab	13.67±0.42ab	12.43±0.32b
Cold carcass weight (kg)	14.50±0.38a	12.86±0.53ab	13.25±0.42ab	12.07±0.32b
Carcass finishing grade (pts)	2.99±0.15a	2.34±0.21ab	2.70±0.17a	1.93±0.13b
Carcass conformation grade (pts)	2.79±0.13	2.51±0.18	2.83±0.14	2.81±0.11
Carcass pelvic-renal fat grade (pts)	2.15±0.13	1.94±0.18	2.04±0.14	1.74±0.11
Hot carcass yield (%)	44.03±0.51b	45.14±0.72b	49.03±0.56a	41.57±0.44c
Cold carcass yield (%)	42.89±0.53b	44.01±0.75b	47.52±0.59a	40.37±0.45c
Loss by cooling (%)	2.68±0.22	2.47±0.31	3.12±0.24	2.90±0.19
Biological yield (%)	56.55±0.37b	58.48±0.53a	57.68±0.41ab	58.06±0.32a
Hot carcass pH	5.84±0.07c	6.39±0.10b	6.07±0.08bc	7.27±0.06a
Cold carcass pH	5.70±0.06b	6.04±0.08a	5.75±0.06ab	5.90±0.05a
Hot carcass temperature (°C)	30.54±0.48b	36.50±0.67a	25.61±0.53c	26.34±0.41c
Cold carcass temperature (°C)	15.89±0.28a	12.14±0.40c	14.63±0.31b	13.74±0.24b

Averages with different letters differ by Bonferroni test ($p < 0.05$).
Initial and final weight and daily weight gain corresponds to finishing period.

Inês, Dorper, Brazilian Somali) whose sizes are different. Fernandes Júnior et al. (2013) estimated in 60.64±1.21 cm the internal carcass length of Santa Inês lambs and in 54.40±1.65 cm the same trait in Brazilian Somali lambs. This can explain the observed differences for leg length, external carcass length and perimeter croup, since some groups could have more casually effects of one breed than other.

We evaluated the commercial cuttings marketed by Guaiúba Farm and Slaughterhouse (anterior and posterior loin, leg, neck, shoulder, rib and breast). The differences observed among the groups for the cold carcass weight and the carcass yields could be represented by the differences in the yields of only two of the cuttings (anterior loin and breast; Table IV), since, according to the law of anatomic harmony (Boccard and Dumont 1960), carcasses with similar weight and amounts of fat will be in equivalent proportions for almost all body regions. The leg and the anterior and posterior loin are the prime cuts of the carcass, considered the most valued in the market. This set represented approximately 48% of the carcass. The averages yields of the leg were slightly lower than that reported by Silva et al. (2012) in Morada Nova lambs (32.00%), fed with silk flower hay, and Moura Neto et al. (2014), in Santa Inês lambs (31.91%), fed with mango bran substituting 100% of corn in the feed. However, Almeida et al. (2015) observed lower yields than those reported in this study for leg (27.39%), shoulder (15.45%) and neck (5.71%) in crossbred of Santa Inês breed, fed with waste from the processing of fruit agribusiness.

TABLE III
Least-square means for traits related to the morphometry of the carcass of the commercial lambs raised in confinement according to slaughter group.

Trait	Least-square means ± standard error			
	Group 1 (n = 30)	Group 2 (n = 38)	Group 3 (n = 32)	Group 4 (n = 42)
External carcass length (cm)	73.97±0.70	73.96±0.98	75.75±0.78	74.14±0.60
Thorax perimeter (cm)	68.82±0.61a	64.88±0.86b	66.04±0.68b	63.99±0.52b
Croup perimeter (cm)	51.05±0.72a	45.69±1.01b	52.89±0.80a	50.51±0.62a
Leg perimeter (cm)	33.77±0.39	33.84±0.55	33.14±0.43	32.88±0.33
Leg length (cm)	29.94±0.41b	42.28±0.57a	26.48±0.45c	26.67±0.35c
Carcass depth (cm)	26.70±0.32a	25.83±0.45ab	25.48±0.35b	24.36±0.27b

Averages with different letters differ by Bonferroni test ($p < 0.05$).

TABLE IV
Least-square means for carcass cutting yields of the commercial lambs raised in confinement according to slaughter group.

Traits	Least-square means ± standard error			
	Group 1 (n = 30)	Group 2 (n = 38)	Group 3 (n = 32)	Group 4 (n = 42)
Anterior loin (%)	12.36±1.24a	10.52±1.75ab	8.45±1.38b	8.63±1.06b
Posterior loin (%)	6.88±0.17	6.95±0.25	7.19±0.19	6.82±0.15
Leg (%)	30.06±0.40	31.64±0.56	30.27±0.44	31.31±0.34
Neck (%)	8.16±0.15b	9.08±0.21a	8.88±0.16a	8.82±0.13a
Shoulder (%)	17.92±0.59	19.45±0.83	19.90±0.65	18.96±0.50
Rib (%)	14.69±0.25	14.79±0.35	15.35±0.27	15.02±0.21
Breast (%)	6.90±0.16a	5.50±0.22b	5.71±0.18b	6.22±0.14b

Averages with different letters differ by Bonferroni test ($p < 0.05$).

Regarding the visual loin assessments, slaughter groups were homogeneous in only two of the five traits evaluated. This uniformity was only for the meat and fat texture grade (Table V). The average for loin eye area (7.37 cm^2) presented by Araújo et al. (2014), for crossbred lambs (Santa Inês x Pantaneiro) was superior only to the average in groups 2. However the average of 0.2 mm observed by these authors for the backfat depth was lower than those estimated here. Farias et al. (2015), reported higher averages (16.58 cm^2 and 2.42 mm) for these same traits, in Suffolk lambs, which are more specialized than those studied here. Cartaxo et al. (2011), observed averages for marbling, texture and color of the flesh, respectively, 1.47, 2.00 and 1.72 for Santa Inês, 4.00, 4.00 and 4.00 for Dorper x Santa Inês and 3.97, 3.91 and 3.94 for Santa Inês x Undefined Breed lambs.

Despite the differences among the groups for the color of the loin, the averages ranging from 3.00-3.51 pts ranked the meat between light red and red (3-4 points). Hopkins et al. (2007) stated that the color intensity can encourage the marketing of the meat as it indicates that comes from young animals, preferred by consumers. Although there were statistical differences among the groups, they produced meat in the best color scale accepted by consumers (Table V). The scores of marbling (between 1.57-2.28 pts) indicated that there was little deposition of intramuscular fat in the lamb carcasses. Marbling and color becomes more intense with advancing age of the animals, and is influenced by the genotype. Most marbling occurs on lambs of breeds which have higher fat deposition at early ages (Cezar and Sousa 2007). The low marbling of this study probably occurred due to the little specialty for meat production of the lambs. The shortening of the sarcomere by cold can be minimized when the carcasses have a good fat finishing grade. Subcutaneous fat serves as a thermal insulator, reducing the cooling rate of the carcasses. Thus, the thickness and distribution of fat contribute to smaller cooling losses. Despite the low value of the thickness of fat in the loin (maximum 1.74 mm) and low average score for the distribution of fat (maximum 2.06) there was no great loss by cooling (2.47-3.12%) in this study.

The macro differences (weight, yields, etc.) among the slaughter groups noted in this study did not influence the micro aspects related to the quality of the meat, such as the physicochemical, except for the hardness of the meat (Table VI) and the fatty acid profile (Table VII). These results reveal the most troubling differences, since they are not perceived by consumers, who are the most important claimants of the food product, and thus

TABLE V
Least-square means for the visual appraisals[1] and quantitative analyses of the loin of the commercial lambs raised in confinement according to slaughter group.

Trait	Least-square means ± standard error			
	Group 1 (n = 30)	Group 2 (n = 38)	Group 3 (n = 32)	Group 4 (n = 42)
Loin eye area (cm^2)	7.48±0.26a	7.14±0.36ab	7.60±0.28a	6.41±0.22b
Backfat depth (mm)	1.74±0.14a	1.22±0.19ab	1.68±0.15a	1.20±0.12b
Marbling grade (pts)	2.28±0.11a	2.03±0.16ab	1.84±0.13b	1.57±0.10b
Fat distribution grade (pts)	2.06±0.13a	2.04±0.19ab	1.46±0.15bc	1.23±0.11c
Fat texture grade (pts)	2.90±0.05	2.98±0.07	2.90±0.05	2.92±0.04
Meat texture grade (pts)	3.65±0.13	3.45±0.19	3.68±0.15	3.85±0.11
Color grade (pts)	3.51±0.10a	3.00±0.14b	3.22±0.11ab	3.49±0.08a

Averages with different letters differ by Bonferroni test ($p < 0.05$);
[1] Scale of 5 pts (1= light pink; 5 = dark red).

TABLE VI
Least-square means for physical-chemical traits in the meat of the commercial lambs raised in confinement according to slaughter group.

Trait	Least-square means ± standard error			
	Group 1 (n = 10)	Group 2 (n = 10)	Group 3 (n = 10)	Group 4 (n = 10)
Water holding capacity (%)	45.28±1.08	41.47±3.22	42.94±1.55	42.11±1.86
Cooking losses (%)	41.19±1.36	44.11±4.04	34.50±1.94	38.55±2.34
Shear force (kgf/cm^2)	8.16±0.83	6.65±1.73	6.98±1.07	9.45±1.31
Moisture (%)	74.57±0.33	76.37±0.98	74.85±0.47	73.62±0.57
Ashes (%)	4.12±0.13	4.04±0.39	4.26±0.19	3.98±0.22
Protein (%)	22.52±0.35	23.87±1.04	23.45±0.50	23.00±0.60

Averages with different letters differ by Bonferroni test ($p < 0.05$);
* Sensory analysis was possible only for groups 1 and 2, due the availability of panelists.

may not require significant changes in the system to standardize the product marketed.

Rodrigues et al. (2008) observed values for water holding capacity between 58.5% and 62.5%, and for cooking losses between 19.2% and 22.5%. Fernandes et al. (2011) reported averages of 63.63% for water holding capacity, 20.53% for cooking losses and 2.18 kgf/cm^2 for shear force. The averages for these traits estimated in this study indicate that the meat quality was below the reported in the literature. This can show that there are important differences in the meat produced in the commercial farms and those from the designed studies, with the use of adequate genotypes and management practices.

Highest fat content was verified in group 3, despite it not differing from groups 1 and 4. This study confirmed the most frequent fatty acids in the meat lamb (oleic, stearic and palmitic acid). Lôbo et al. (2014) reported that these acids represent about 78% of the total of fatty acids. The small differences between the slaughter groups may be important, confirming the lack of standardization of the product available to the market. This factor may be significant to the consumer, considering, for example, that cholesterol plasma concentration is influenced by the fatty acid composition of the diet and palmitic fatty acid (C16:0) increases this concentration, while the acid oleic (C18:1n9c) decreases. Thus, the meat of the lambs of the groups 3 and 4 tend to predispose to this increase by having greater amount of palmitic acid and lower concentration of desirable fatty acids. Conjugated linoleic acid (CLA), a mixture of positional and geometric isomers of octadecadienoic acid with conjugated double bonds, has been considered beneficial to human health due to its anti-carcinogenic and metabolic properties. In ruminants, the main isomers found are the C18:2c9t11 involved in anti-carcinogenic action, and the isomer C18:2t10c12, particularly involved in the regulation of fat synthesis in the body, being the only ones to have recognized biological activity (Demirel et al. 2004). Likewise, the major difference among the groups for the C18:2c9T11 confirmed the lack of standardization of the product, with regard to CLA.

CONCLUSIONS

Our study revealed the inefficiency of this type of commercial model of production and slaughter of undefined crossbred lambs. The use of animals without specificity for meat production, amongst with the absence of better control in the reared phase, contribute to greater variability of performance, reduced growth rate of lambs, the periods of confinement, lack of standardization of groups for slaughter aside from the final product sent to the consumer market.

TABLE VII
Total intramuscular fat content and fat acid profile in the meat of the commercial lambs raised in confinement according to slaughter group.

	Least-square means ± standard error			
	Group 1 (n = 10)	Group 2 (n = 10)	Group 3 (n = 10)	Group 4 (n = 10)
Total fat content (mg/g)	15,10ab	12,49b	18,67a	17,47ab
Saturated (%)	41.57±0.93b	43.80±1.93ab	46.72±1.11a	46.02±1.14a
Myristic acid - C14:0 (%)	1.12±0.17	1.31±0.36	0.36±0.21	0.30±0.21
Pentadecanoic acid - C15:0 (%)	0.17±0.02	0.22±0.04	-	-
Palmitic acid - C16:0 (%)	18.26±0.70c	18.72±1.46bc	24.12±0.84a	23.28±0.86ab
Margaric acid - C17:0 (%)	0.84±0.12a	1.09±0.24a	0.18±0.14b	0.08±0.14b
Stearic acid - C18:0 (%)	21.19±0.66	22.47±1.37	22.07±0.79	22.37±0.81
Monounsaturated (%)	50.92±2.45a	49.65±5.10ab	42.13±2.93b	45.29±3.01b
Palmitoleic acid - C16:1 (%)	0.80±0.11a	0.92±0.23a	0.24±0.13b	0.16±0.13b
Heptadecanoic acid - C17:1 (%)	0.39±0.03	0.47±0.06	-	-
Elaidic acid - C18:1n9t (%)	1.92±0.18a	2.56±0.38a	0.76±0.22b	0.65±0.22b
Oleic acid - C18:1n9c (%)	42.71±2.52	39.79±5.25	41.15±3.02	44.47±3.10
Eicosapentaenoic acid - C22:1n9 (%)	4.49±0.45	5.16±0.94	-	-
Nervonic acid - C24:1 (%)	0.61±0.08	0.75±0.16	-	-
Polyunsaturated (%)	7.50±2.39	6.54±4.98	11.15±2.86	8.69±2.95
Linoleic acid - C18:2n6c (%)	6.38±2.18	5.88±4.54	9.00±2.61	6.63±2.68
CLA^{A} - C18:2c9T11 (%)	0.50±0.03a	0.49±0.07a	0.02±0.04b	0.02±0.04b
CLA^{B} - C18:2t10c12 (%)	0.09±0.03	0.23±0.07	-	-
α-linolenic - C18:3n3 (%)	0.30±0.03	0.40±0.06	-	-
Gamma-linolenic - C18:3n6 (%)	0.14±0.02	0.19±0.04	-	-
Arachidonic acid - C20:4n6 (%)	-	-	2.15±0.49	2.06±0.50
Total unsaturated (%)	58.43±0.93a	56.19±1.93ab	53.28±1.11b	53.98±1.14b
Desirable (%)	79.61±0.73a	78.66±1.52ab	75.35±0.87b	76.35±0.90b
ID[1]	0.67±0.03	0.64±0.07	0.61±0.04	0.66±0.04
ID1[2]	0.04±0.00a	0.05±0.01a	0.01±0.00b	0.01±0.00b
ID2[3]	0.52±0.03	0.50±0.05	0.45±0.03	0.49±0.03
Polyunsaturated/Saturated	0.18±0.05	0.15±0.10	0.24±0.06	0.19±0.06
Monounsaturated/Saturated	1.22±0.06a	1.15±0.12ab	0.92±0.07b	0.99±0.07b
Polyunsaturated/Monounsaturated	7.04±1.13	7.59±2.35	8.22±1.35	6.07±1.39

Averages with different letters differ by Bonferroni test ($p < 0.05$);
CLA = conjugated linoleic acid;
Desirable = total unsaturated + C18:0;
[1] Desaturase index (ID) = C18:1n9c / (C18:0 + C18:1n9c);
[2] Desaturase index (ID1) = C16:1 / (C16:0 + C16:1);
[3] Desaturase index (ID2) = (C18:1n9c + C16:1) / (C18:0 + C18:1n9c + C16:0 + C16:1).

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