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Short communication

Carcass traits and meat quality differences between a traditional and an intensive production model of market lambs in Brazil: Preliminary investigation

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ABSTRACT

The objective of this study was to determine the differences of carcass traits and meat quality of market lambs between a traditional and an intensive production model. Eighty lambs were obtained from four commercial farms. At the Traditional model 20 lambs were Dorper × Santa Inês and 20 Ile de France. Farms from intensive model provided 20 Texel lambs and 20 Dorper × Santa Inês lambs. Animals from intensive model had access to creep feeding until weaning and were fed with a total mixed ration with 90% of concentrate at the finishing. The intensive model provided higher loin eye area and fat thickness, and lower shear force of the loin ($P < 0.0001$). The Traditional model presented higher rate of polyunsaturated fatty acids ($P < 0.01$) and lower ω6:ω3 rate ($P < 0.0001$). The loin of the animals from the intensive model presented more intense aroma and taste and higher juiciness and chewiness ($P < 0.05$). The intensive model produced carcasses with better conformation and fatness and soft meat with better color, taste and texture.

1. Introduction

Sheepmeat production is considered an activity with great growth potential in Brazil. Data from FAO (2013) point out that the country has approximately 17.7 million sheep, what represents a growth of 20% in a period of ten years and a proof of the importance of the activity for the national agribusiness. However, the sectors of the productive chain must search for a higher integration to reach the consolidation of the activity, seeking the economic efficiency for the breeder, stability of the production scale and certificate of quality of the meat products offered to the consumers.

The agricultural production system of the State of São Paulo (southeast region) is made up by 77.7% of farms with less than 50 ha. The sheep herd has 507,694 heads, made up by dual-purpose and specialized breeds for meat production in commercial herds and breeders. The size of the farms and the high prices of the lands for agricultural purposes require the adoption of intensive practices of management and production of the animals, aiming to increase the productivity.

Our objective was to evaluate if the technical criteria related to the production system, slaughter and carcass traits obtained by an intensive model of lamb meat production, called Cordeiro Paulista, promote the production of quality carcass and meat.

2. Material and methods

Animal procedures were not reviewed and approved by the Universidade Federal da Grande Dourados (UFGD) and Universidade Estadual Paulista (UNESP) Animal Care and Use Committee because this experiment did not involve animals originating from or under the control of UFGD and UNESP.

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Table 1
Description of the production models.

Item	Characteristic	Traditional	Cordeiro Paulista
Production	Sex	Entire male	Entire male
	Breed	Dorper × Santa Inês and Ile de France	Dorper × Santa Inês and Texel
	Suckling period	Under pasture[a]	With creep feeding
	Finishing period	Under pasture	Feedlot
Weight	Birth	4.7 ± 0.8 kg	4.3 ± 0.7 kg
	Weaning	22.4 ± 2.9 kg	20.4 ± 4.3 kg
Age	Weaning	73.6 ± 5.9 days	60.1 ± 6.9 days
	Slaughter	179.5 ± 27.4 days	120.4 ± 9.7 days

[a] *Brachiaria* spp. for Dorper × Santa Inês lambs, and *Cynodon* spp. for Ile de France.

2.1. Sampling and production models

The experiment was carried out in the cities of Araçatuba (21°12′32″S, 50°25′58″O) and São Manuel (22°43′52″S, 48°34′14″O), in the State of São Paulo (southeast region), Brazil. Four farms were used, where two were considered as Traditional production model and the other two employed the Cordeiro Paulista intensive production model. The description of the production models is shown in Table 1. Twenty entire male lambs from each farm were randomly chosen at the moment of trading to slaughter, resulting in 40 lambs from Traditional model and 40 from Cordeiro Paulista to be evaluated. Generally, for market lambs the slaughter weight ranges between 30 and 35 kg, but each farm decided the moment of trade. At the slaughter all lambs showed milk teeth.

Within Traditional production model, both farms maintained the lambs with their moms until the weaning, without access to creep feeding. One farm raised Dorper × Santa Inês lambs which were finished under *Brachiaria* spp. pasture. The other farm raised Ile de France lambs finished under *Cynodon* spp. pasture. The average age of weaning and slaughter was 73.6 ± 5.9 and 179.5 ± 27.4 days, respectively. The two farms produced their lambs from the breeding season of 2012. The average birth and weaning weight for Traditional model were 4.7 ± 0.8 and 22.4 ± 2.9 kg, respectively.

Each farm of Cordeiro Paulista model followed the technical criteria of production presented in Table 1. One farm raised Texel lambs and the other Dorper × Santa Inês lambs. At both farms for the creep feeding and feedlot the lambs received commercial diets ad libitum. The concentrate used in the creep feeding and in the feedlot diet was the same, made up with crushed corn, soy bean meal, extruded whole soy, mineral and vitamin premix, limestone and sodium bicarbonate. At finishing lambs were fed with a total mixed ration with roughage to concentrate ratio of 10:90, with Coast cross (*Cynodon* spp.) hay. Both farm made the breeding season at the same year that the two farms of Traditional production model. The average birth and weaning weights and age at weaning and slaughter of Cordeiro Paulista were 4.3 ± 0.7 and 20.4 ± 4.3 kg, and 60.1 ± 6.9 and 120.4 ± 9.7 days, respectively.

2.2. In vivo *and carcass evaluations*

The body weight (BW, kg), the body condition (BC) according to the methodology described by Russel et al. (1969), the ultrasound loin eye area (ULEA, cm^2) and subcutaneous fat thickness (USFT, mm) were recorded at the moment of trading the animals for slaughter. ULEA and USFT were determined by the analysis of ultrasound images (Chison 8300 VET with multifrequential linear transducer of 3.5 MHz, Chison Medical Imaging Co. Ltd., Jiang Su province, China) collected on the m. *Longissiumus*, between the 12th and the 13th rib, with the aid of the open code software ImageJ (http://rsbweb.nih.gov/ij/). ULEA values were used to determine the relative ULEA, calculated in relation to the BW of the animals (ULEA:BW, cm^2/kg).

The slaughter of the animals was carried out in commercial slaughterhouses commonly used by the farms used in the experiment. Hot carcass weight (HCW, kg) and hot carcass yield (HCY, %) were recorded after slaughtering, determined by the ratio between HCW and BW (HCY = [HCW ÷ BW] × 100). Each carcass was subjectively evaluated as for conformation and fatness by a trained technician, according to the European scheme of sheep carcass classification (EEC Regulation no. 22, 2008). Only the percentage in function of the conformation and fatness class was determined, obtained in relation to the number of carcasses evaluated in each production model.

2.3. Meat quality

Following the chilling of the carcasses and the production of the commercial cuts, the boneless loin (m. *Longissiumus*) from left and right side, placed between the first and the last lumbar vertebra, was used to determine colour components, subjective colour, water holding capacity (WHC) of cooked meat, shear force (SF, kg), fatty acids profile and sensorial properties. The loins were vacuum packaged and frozen for laboratory analysis. The colour components, WHC and SF were determined according to Honikel (1998) methodology using loins of left side of carcasses. One week after slaughter samples were thawed overnight and slices of 2.5 cm were taken for each analysis, resulting into 40 samples of each production model for colour, WHC, and SF.

CIE L*a*b* coordinates ("L*" lightness, "a*" redness, "b*" yellowness) were measured on the surface of m. *Longissimus*, after removal of the connective tissue band (Chroma Meter CR-400 colorimeter with standard illuminant D65; KONICA MINOLTA Sensing Inc., Japan). The subjective color was determined by comparing the samples to color standards varying from pink to brown, in a growing scale from 1 to 7 points.

Loin samples from right side of the carcasses were used to fatty acid profile and sensorial analysis. Fatty acids were analyzed by extraction of total lipids from 4.0 g of wet samples, using chloroform/methanol (2/1; v/v) by a period of ten minutes, according to Folch et al. (1957). One microliter of fatty acid methyl esters pipetted from supernatant were quantified by gas-chromatography (SHIMADZU – GC 17A), using a flame ionization detector, "Split/splitless" injector, DB-Wax capillary columm (60 m × 0,25 mm; J&W Scientific). For all saponification process were used methanol, chloroform, and KCL 0.88% as chemicals.

The initial column temperature was held at 80 °C for 2 min at a rate of 3 °C/min and then raised to 180 °C at a rate of 30 °C/min, kept at this temperature for 30 min, and after this time, raised to 200 °C at a rate of 3 °C/min, remaining at this temperature for 108 min. The detector temperature 240 °C with helium carrier gas total flow of 8.0 mL/min; splitter ratio 1:50. For the identification of fatty acids were compared with the retention times of the methyl esters of standards (Sigma–Aldrich), while the measurement was carried out by area normalization expressing the result as a percentage area of each acid on the total area fatty acids (%), according to the methodology of Hartman and Lago (1973).

The sensorial analysis was carried out by ten trained panelists. The samples were prepared according to the methodology described by Sañudo et al. (1998) and the evaluation comprehended aroma intensity, strange aroma, flavor, strange flavor, tenderness, juiciness and chewiness. A 9 cm, non-structured scale was used for aroma, flavor and chewiness and a structured scale from 1 to 9 points was used for strange aroma, strange flavor, tenderness and juiciness.

The sensorial characteristics were described as: aroma intensity – from absent to very intense and typical aroma of the sheep meat;

strange aroma – none (1), extremely weak (2), very weak (3), weak (4), moderately weak (5), moderately strong (6), strong (7), very strong (8), and extremely strong (9); flavor: without typical flavor to intense and typical flavor of the sheep meat; strange flavor – none (1), extremely weak (2), very weak (3), weak (4), moderately weak (5), moderately strong (6), strong (7), very strong (8), and extremely strong (9); tenderness – extremely tender (1), very tender (2), moderately tender (3), tender (4), neither tender nor hard (5), weakly hard (6), moderately hard (7), very hard (8), and extremely hard (9); juiciness – extremely dry (1), very dry (2), moderately dry (3), dry (4), neither dry nor juicy (5), weakly juicy (6), moderately juicy (7), very juicy (8), and extremely juicy (9); chewiness – from elastic, hard to swallow, to easily disintegrated in the mouth, easy to swallow.

2.4. Statistical analysis

The data were analyzed by GLM procedure of SAS, version 9.2 (SAS Institute, Cary, NC, USA) and submitted to the Shapiro-Wilk test to verify the normality of the residues and to the Barlett test to verify the homogeneity among the variances. The effects of the production model were studied and the averages of the variables which showed difference were compared by the t test, at the significance level of 5%. The analysis of sensorial data was made according to Font i Furnols and Guerrero (2005).

3. Results

The animals from the Cordeiro Paulista model presented increased BW, BC, ULEA, ULEA:BW, USFT, HCW, and HCY (Table 2). For the Traditional model 47.5% of the carcasses presented reasonable conformation class (O) and half of them presented fatness class 2 (slight). By combining the conformation and fatness classes, 32.5% of the carcasses of the Traditional model were classified as O2. The Cordeiro Paulista model presented 46.51% of the carcasses with good conformation (R) and 37.21% with fatness class 4 (abundant), resulting in 18.6% of the carcasses classified as R3 (Table 3).

The production model influenced the instrumental traits and the subjective colour of the loin (Table 4). The lambs produced in the Cordeiro Paulista model presented increased L*, a*, b*, and WHC and decreased subjective colour and SF. There was effect of the production model on the undecanoic (C11:0), pentadecanoic (C15:0) and heptadecanoic (C17:0) saturated fatty acids and pentadecenoic (C15:1), heptadecenoic (C17:1), elaidic (C18:1ω9t), linolelaidic (C18:2ω6t), linolenic (C18:3ω3), gamma linolenic (C18:3ω6), C20:3ω3 and C20:3ω6 unsaturated fatty acids of the loin, with increased values for the Traditional model (Table 5).

Table 2
Effect of the production model on in vivo and carcass traits.

Item[a]	Production model		SEM[b]	P
	Traditional	Cordeiro Paulista		
BW, kg	32.6	37.1	0.54	***
BC	2.84	3.58	0.06	***
ULEA, cm^2	12.74	17.46	0.45	***
ULEA:BW, cm^2/kg	0.39	0.47	0.01	**
USFT, mm	1.74	2.35	0.05	***
HCW, kg	13.9	18.1	0.31	***
HCY, %	42.8	48.5	0.33	***

*$P < 0.05$, ns = not significant.
[a] Body weight (BW); body condition (BC); ultrasound loin eye area (ULEA); ultrasound subcutaneous fat thickness (USFT); hot carcass weight (HCW); hot carcass yield (HCY).
[b] Standard error of the mean (SEM).
** $P < 0.01$.
*** $P < 0.0001$.

Table 3
Carcasses ratio (%) classified according to the conformation and fatness class in function of the production model.

Fatness class	Conformation class[a]					Total
	E	U	R	O	P	
	Traditional					
Very abundant (5)						
Abundant (4)		2.5	2.5			5
Medium (3)		2.5	17.5	5		25
Slight (2)			10	32.5	7.5	50
Reduced (1)				10	10	20
Total		5	30	47.5	17.5	
	Cordeiro Paulista					
Very abundant (5)		13.95	6.98			20.93
Abundant (4)	4.65	16.28	16.28			37.21
Medium (3)	2.33	11.63	18.60	2.33		34.89
Slight (2)			4.65	2.33		6.98
Reduced (1)						
Total	6.98	41.86	46.51	4.66		

[a] Excellent (E); Very good (U); Good (R); Fair (O); Poor (P).

Table 4
Qualitative traits of the loin (m. *Longissimus*) of lambs in two production models.

Item[a]	Production model		SEM[b]	P
	Traditional	Cordeiro Paulista		
L*	39.3	43.9	0.36	***
a*	15.9	19.4	0.43	**
b*	10.1	11.7	0.19	**
Subjective colour[c]	5.4	2.9	0.23	***
WHC, %	51.6	60.8	1.97	*
SF, kg	5.9	3.4	0.28	***

ns = not significant.
[a] Lightness (L*); Redness (a*); Yellowness (b*); Water holding capacity (WHC); Shear force (SF).
[b] Standard error of the mean (SEM).
[c] Subjective colour: scale from 1 (pink) to 7 (brown).
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.0001$.

The Cordeiro Paulista model presented increased ratio of oleic (C18:1ω9c) and C22:2.

There was no difference between the total ratio and relation of unsaturated and saturated fatty acids between the production models (Table 5). The Traditional model presented increased total ratio of polyunsaturated fatty acids and ω3, while the Cordeiro Paulista model obtained increased ratio of monounsaturated fatty acids and C18:1ω9. These differences resulted in better ω6: ω3 ratio for the Traditional model (2.44 vs 7.22).

The sensorial characteristics of aroma intensity, flavor, juiciness and chewiness were influenced by the production model (Table 6). The loin of the animals produced in the Cordeiro Paulista model presented more intense aroma and flavor, typical of sheep meat, in comparison to the Traditional model. Juiciness and chewiness had increased scores for samples of the Cordeiro Paulista model.

4. Discussion

Each sheep breed has advantages and disadvantages across traits related to meat production, and no single breed excels for all growth, carcass, and quality traits. Terminal breeds have greater growth rate, larger loin eye area, and leaner carcasses. Prolific breeds have more tender meat than terminal breeds. General purpose hair and wool breeds show intermediate values for growth, carcass, and quality traits to terminal and prolific breeds (Shackelford et al., 2012). The most outstanding difference between the breeds on the quality traits, whether the carcass or meat, is the

Table 5
Fatty acids composition (percentage of the total fatty acids) of the loin (m. *Longissiumus*) cut from lambs produced in two production models.

Fatty acids	Production model		SEM[a]	P
	Traditional	Cordeiro Paulista		
C13:0	0.29	0.21	0.02	ns
C14:0	3.14	2.27	0.24	ns
C15:0	0.03	0.01	0.003	*
C15:1	0.02	0.01	0.001	*
C16:0	21.71	23.38	0.51	ns
C16:1	2.90	2.06	0.22	ns
C17:0	0.12	0.02	0.02	*
C17:1	0.36	0.26	0.02	*
C18:0	16.35	15.96	0.57	ns
C18:1ω9	41.23	46.85	0.73	**
C18:2ω6	3.58	3.23	0.19	ns
C18:3ω3	2.04	0.48	0.10	***
C18:3ω6	0.29	0.08	0.02	**
C20:0	1.25	0.33	0.36	ns
C20:1	0.80	0.80	0.04	ns
C20:2	1.16	1.14	0.07	ns
C20:3ω3	0.21	0.10	0.006	***
C20:3ω6	0.90	0.59	0.05	*
C20:4ω6	1.04	0.24	0.39	ns
C22:0	1.02	0.76	0.09	ns
C22:1ω9	0.36	0.30	0.02	ns
C22:2	0.16	0.28	0.02	**
C23:0	0.34	0.20	0.05	ns
C24:1	1.38	0.56	0.30	ns
Unsaturated	55.67	56.72	0.82	ns
Polyunsaturated	9.35	6.09	0.46	**
Monounsaturated	46.32	50.63	0.81	*
Saturated	44.33	43.28	0.82	ns
Unsaturated:saturated	1.27	1.32	0.04	ns
Polyunsaturated:saturated	0.21	0.14	0.01	**
ω3	2.46	0.58	0.18	***
ω6	5.61	4.09	0.43	ns
ω6:ω3	2.44	7.23	0.31	***

ns = not significant.
[a] Standard error of the mean (SEM).

Table 6
Sensorial traits of the loin (m. *Longissiumus*) of lambs in the two production models.

Item[a]	Production model		SEM[b]	P
	Traditional	Cordeiro Paulista		
Aroma intensity	3.84	6.09	0.51	*
Strange aroma	1.13	1.38	0.11	ns
Flavor	3.20	5.46	0.50	*
Strange flavor	1.70	1.60	0.20	ns
Tenderness	4.20	3.50	0.32	ns
Juiciness	5.00	6.67	0.40	*
Chewiness	4.20	6.03	0.37	*

** $P < 0.01$, *** $P < 0.0001$, ns = not significant.
[a] Aroma intensity, flavor and chewiness: scale from 0 to 9 cm; strange aroma, strange flavor, tenderness and juiciness: scale from 1 to 9 points.
[b] Standard error of the mean (SEM).
* $P < 0.05$.

fat partition among depots and their distribution through the animal's body. This is a result of differences in adult size and precocity (Sañudo et al., 1997), which are reflected in the most tender meat of prolific breeds, for example.

The effect of slaughter weight on carcass and meat quality traits is explained by the phenomenon of growth and development of animals. Hammond (1940) defines growth as increase in mass, or weight, until the animal reaches the adult size, and development as the changing of forms and body conformation. Butterfield (1988) describes that the major change that occurs in the development of carcass components are the change of muscle, fat, and bone proportions. The muscle and fat represent the edible portion and shows higher commercial value. The weight gain results in an increased muscle and fat, with higher or lower fat gain dependent of the genotype. The works of Lambuth et al. (1970), Solomon et al. (1980), Santos-Silva et al. (2002), Kremer et al. (2004), Pérez et al. (2007), and Abdullah and Qudsieh (2011) corroborate this information, showing greater muscularity, conformation and fatness, and consequently specific qualitative attributes due to the higher amount of fat, as the slaughter weight increases.

The production models evaluated showed a similarity to use meat breeds and crosses directed to the production of meat, with a meat breed as terminal sire. In general, at the state of São Paulo this practice is common, even in farms with low technology. This contributed to minimize the effects of breed within and between the production models. The main effects were due the production model where the Cordeiro Paulista provided younger and heavier lambs with better body condition, higher muscularity and better fatness. The meat from Cordeiro Paulista lambs showed better quality attributes as better colour, lower shear force, and better sensorial traits. Even with lower ω3 content for Cordeiro Paulista meat, there wasnít difference for the proportion of unsaturated fatty acids between the productions models, which was higher than saturated fatty acids.

From the nutritional point of view, the Cordeiro Paulista model presents the disadvantage of lower concentration of ω3 fatty acids and, consequently, higher ω6:ω3 ratio in comparison to the Traditional model. Simopoulos (2002) highlights that high level of ω6, which increases ω6:ω3 ratio, promote cardiovascular diseases, cancer, inflammatory diseases, and autoimmune disorders. Thus, the search for an increase in the level of meat ω3 fatty acids, with a lower ω6:ω3 ratio, can improve the nutritional quality of the meat resulting in benefits for human health.

The employment of creep feeding and finishing in feedlot used in the Cordeiro Paulista model may facilitate diet manipulation in order to change the fatty acids profile of the meat, with an increase in the concentration of ω3 fatty acids. This manipulation may be carried out by using different vegetable-origin ingredients, as occurred in the studies made by Rodrigues et al. (2010) and Karami et al. (2013), and vegetable oils, such as linseed, as suggested by Zhang et al. (2013).

The production system strongly influences animal productivity and the quality of the products, mainly by means of weight and finishing of the animals and kind of diet used. Several works present results of the influence of the production system on the quality of lamb meat and the great importance of the effect of weight and finishing of the animals and the relations between diet, fatty acids profile and sensorial characteristics, such as aroma and flavor (DíAlessandro et al., 2012; Fisher et al., 2000; Melton, 1990; Sañudo et al., 1996, 1998, 2000, 2007; Duckett and Kuber, 2001; Geay, 2001; Font i Furnols et al., 2006, 2009; Resconi et al., 2010).

In fact, the Traditional production model should be more characterized, especially in relation to the composition of the diet of the animals, aiming to elucidate the differences of aroma and flavor intensities between the production models, once the results obtained are opposite to the ones found by Sañudo et al. (2000), who determined positive correlations between meat aroma, flavor and ω3 fatty acids content from diets based on forages, and negative correlations of these sensorial characteristics with ω6 fatty acids content from diets based on concentrates.

Probably, the typically higher intense aroma and flavor found in the meat from the Cordeiro Paulista model is due to the higher carcass fatness of the animals produced in this model, in agreement with the results presented by Muela et al. (2010), who associated the higher intensity of these sensorial characteristics to the aromatic composts present in the higher amount of fatty tissue in the carcass. Carcasses from Cordeiro Paulista model showed higher subcutaneous fat thickness and better fat cover distribution. As the fatness increase is observed a higher contribution of fatty acids from triglycerides that show higher proportion of monounsaturated fatty acids. Meat samples from Cordeiro Paulista showed higher proportion of C18:1 (Table 5) and according to Dryden and Maechello (1970), Westerling and Hedrick (1979), and Zembayashi et al. (1995) this fatty acid is correlated with high flavor scores in panel evaluations.

Resconi et al. (2010) emphasize the inconsistence of the results of the effects of the diet on the aroma and flavor of the sheep meat because some studies report more intense aroma and flavor with animals fed with more concentrate than pasture and other studies present opposite results. However, the authors point out the higher influence of the aromatic composts on aroma and flavor of the sheep meat in comparison with the effects of the fatty acids, and determined that the intensification of the production system by using diets based on concentrate affects the aromatic composts concentrations, making the aroma and taste of the meat more intense.

5. Conclusion

The farms considered in the Cordeiro Paulista model produced carcasses with better conformation and fatness and soft meat with better color, flavor and texture.

It is necessary to make a better evaluation of the ingredients composition of the diet of the animals in order to adjust the composition of polyunsaturated fatty acids, especially ω3.

Conflicts of interest

None.

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