Lipid composition and sensory traits of meat from Pantaneiro lambs slaughtered with different subcutaneous fat thickness

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ABSTRACT. Lipid composition and sensory traits of the meat from female lambs of the Pantaneiro genetic group slaughtered with 2.00, 3.00 and 4.00 mm of subcutaneous fat thickness (SFT) were evaluated by ultrasound. Twenty-four lambs weighing 16.24 ± 1.78 kg were confined in feedlots. These animals were fed with pelleted diet formulated to provide a daily weight gain of 0.30 kg. As the lambs reached the pre-set SFT in the weekly evaluation by ultrasound, they were slaughtered on the day following the measurement, regardless of their weight. The SFT did not alter the fatty acid profile of meat from Pantaneiro lambs. For the sensory analysis, the meat from the animals slaughtered with 4.00 mm SFT received the best score for variables overall acceptance and characteristic flavor as compared with the females slaughtered with 2.00 mm SFT. The treatment with 3.00 mm SFT, however, did not differ from the others. For sensory traits odor and juiciness, no effect of SFT was found. It is recommended to slaughter lambs with 3.00 mm thickness of subcutaneous fat on the loin, because covered better number of favorable attributes in sensory analysis.

Keywords: fatty acids, loin, overall acceptance, sheep.

Composição lipídica e características sensoriais da carne de cordeiras Pantaneiras abatidas com diferentes espessuras de gordura subcutânea

RESUMO. Foram analisadas a composição lipídica e as características sensoriais da carne de cordeiras do grupo genético Pantaneiro, abatidas com 2,00; 3,00 e 4,00 mm de espessura de gordura subcutânea (EGS), avaliadas por ultrassonografia. Foram confinadas 24 cordeiras com peso de 16,24 ± 1,78 kg. Os animais foram alimentados com ração peletizada, formulada para um ganho de peso diário de 0,30 kg. Conforme cada cordeira atingia a EGS pré-determinada, na avaliação semanal por ultrassonografia, a mesma era abatida no dia seguinte às aferições, independentemente do peso. A EGS não alterou o perfil de ácidos graxos na carne de cordeiras Pantaneiras. Para a análise sensorial, a carne dos animais abatidos com 4,00 mm de EGS foi melhor pontuada para as variáveis aceitação global e sabor característico quando comparada com as fêmeas abatidas com 2,00 mm. Por sua vez o tratamento com 3,00 mm não diferiu dos demais. Para as características sensoriais odor e suculência não foram verificados efeito da EGS (p ≥ 0,05). Recomenda-se o abate de cordeiras do grupo genético Pantaneiro com 3,00 mm de espessura de gordura subcutânea no lombo, pois englobaram maior número de atributos favoráveis em relação à análise sensorial.

Palavras-chave: ácidos graxos, lombo, aceitação global, ovinos.

Introduction

In the last decade, several researchers have claimed that the presence of saturated fatty acid in food can be considered harmful to human health, especially in that they are related to cardiovascular disease (Hooper et al., 2012). Yet, a few recent research studies state that there is no evidence of this relationship (Siri-Tarino, Sun, Hu, & Krauss, 2010; Malhorta, 2013), indicating only that an excess of this type of feeding may result in damage to health, especially because of the sedentary lifestyle that most consumers have led in current days.

The fatty acids profile of meat lipids has a greater impact on its quality, sensorial characteristics like flavor and tenderness, consumer acceptance, and healthy benefits for humans (Ribeiro, Oliveira, Juchem, Silva, & Nalério, 2011).

The deposition and distribution of body fat in sheep also influence the acceptance of a meat.

Maddock (2013) observed that excessive subcutaneous fat results in lower carcass yields and higher costs of gain, whereas lack of marbling results in lower carcass value and generally lower consumer eating satisfaction. Therefore, thickness of subcutaneous fat is an important factor to all sections of the meat trade.

Ultrasonic measurements and visual conformation scores on live lambs are widely used among farmers to select breeding animals (Einarsson, Eythórsdóttir, Smith, & Jónmundsson, 2015), selection of sheep with higher carcass traits or for predicting the readiness of animals ready for slaughter (Orman, Caliskan, & Dikmen, 2010), unlike the traditional Brazilian method of fixed weight, which varies between 28 and 35 kg.

Because of the difference in physiological maturity between each sheep genetic group, the real-time ultrasound technique may help to define the ideal moment, through the thickness of subcutaneous. Evaluated fat between the 12th and 13th ribs, to slaughter the animals regardless of its weight. This guideline, in addition to providing the market carcasses with good conformation, and appropriate amount of fat, will bring fast economic returns to producers, and the reduction days of confinement.

According Zeola, Souza, Souza, and Silva Sobrinho (2010) the sensory attributes of meat are of particular importance, with priority in research should aim to analyze the influence of the final product. Soon, conducting sensory analysis is a way of understanding the consumer profile of the lamb through your preferences. The case under study here relates the analysis of the meat from lambs of the Pantaneiro genetic group with different subcutaneous fat thicknesses, because the adipose tissue is the parameter of greatest influence on the meat sensory traits.

The objective of this study was to evaluate the lipid and sensory traits of meat from Pantaneiro lambs slaughtered with 2.00, 3.00 and 4.00 mm of subcutaneous fat thickness, evaluated by ultrasound.

Material and methods

Sample collection

The experiment was conducted on The Experimental Farm Iguatemi, at Universidade Estadual de Maringá (UEM), located in Maringá, Paraná State, Brazil. The study was accepted by the Ethics Committee on Animal Use in Experimentation, under protocol DZO021/2014 issued by the university itself.

Twenty-four female lambs at approximately 100 days of age and weighing 16.24 ± 1.78 kg, all of the same genetic group — Pantaneiro — were used. The lambs were acquired from extensive-rearing properties in the southeast region of Mato Grosso State (Brazil).

The animals were distributed randomly into individual covered stalls with suspended slatted floors, and the treatments were defined as the subcutaneous fat thicknesses (SFT) of 2.00, 3.00 and 4.00 at the loin, between the 12th and 13th ribs, evaluated by ultrasound. The animals received water *ad libitum* throughout the entire experimental period, and were fed a total, pelleted diet formulated to provide a daily weight gain of 0.30 kg (National Research Council [NRC], 2007). The diet was supplied once daily *ad libitum* in the morning to allow for 10% leftovers.

The chemical composition of the diet (Table 1) was analyzed at the Laboratory of Animal Nutrition of the Department of Animal Science at UEM, following the methodology described in AOAC (Association of Official Analytical Chemistis, 2000).

Table 1. Ingredients, in g kg^{-1} DM, and chemical composition.

Item	Composition (g kg^{-1})
Oat hay	100.00
Ground corn grain	448.00
Soybean meal	150.00
Soybean hulls	150.00
Rice bran	100.00
Powder molasses	20.00
Ammonium chloride	20.00
Mineral mix[1]	10.00
Zinc bacitracin	2.00
Dry matter	912.80
Crude protein	162.40
Ether extract	42.10
Neutral detergent fiber	275.40
Acid detergent fiber (ADF)	138.60
Ash	45.90
In vitro dry matter digestibility	782.50
Total digestible nutrients (TDN)[2]	766.80
Saturated fatty acids (g 100 g^{-1} TFA[3])	28.72
Monounsaturated fatty acids (g 100 g^{-1} TFA[3])	34.08
Polyunsaturated fatty acids (g 100 g^{-1} TFA[3])	37.20

[1]Guaranteed levels per kg: Calcium 220 g; Phosphorus 130 g; Magnesium 25.5 g; Sulfur 24 g; Iron 3.000 mg; Manganese 1.500 mg; Zinc 4.000 mg; Copper 1.200 mg; Cobalt 280 mg; Iodine 260 mg; Selenium 30 mg; Fluorine 300 mg. [2]TDN estimated by the following equation: % TDN = 92.2 – (1.12 × ADF), described by Aldai et al. (2010). [3]TFA = total fatty acids.

The evaluations by ultrasound and weightings were performed every 15 days. To obtain the SFT, an ultrasound device (HS-1500 VET, Honda) with a 50 mm multi-frequency linear transducer at 7.5 MHz frequency was used. For the measurements, the lambs were immobilized manually and had their hair wool divided in the measurement regions with a comb. Mucilage was applied for a smoother probing.

The transducer's pressure head was maintained minimal to avoid compression of the fat, and all

measurements were taken by the same technician, from the left side, between the 12th and 13th ribs, at 4 cm from the midline of the spine. After the image had been captured, the SFT was measured using the electronic cursor of the ultrasound.

As the lambs reached the pre-set SFT of 2.00, 3.00 and 4.00 mm in the evaluation by ultrasound, they were slaughtered on the day following the measurements, irrespective of their weight.

After having been deprived of solid feed for 18 hours, the animals were stunned by electronarcosis at 220 Volts for 8 s. After bleeding, skinning and evisceration, the carcasses were weighed and then stored in a cold room at 4°C for 24 hours.

The chilled carcasses were sawn lengthwise, and each left side had its *Longissimus dorsi* muscle removed, separated according to Cañeque and Sañudo (2005), identified, vacuum-packed and frozen in a freezer at –18°C.

Fatty acid profile analysis

Samples were collected between the 6th and 10th thoracic vertebra for the fatty acid profile, without the inclusion of subcutaneous fat. Lipids were extracted using the technique described by Folch, Less, and Sloane (1957), with a chloroform/methanol (2:1 v v^{-1}) solution. The methylation of lipids was performed according to the method of Hartman and Lago (1973), using a solution of ammonium chloride and sulfuric acid in methanol as esterifying agent. The fatty acid esters were separated and analyzed on a gas chromatograph (Agilent, model 7890A) coupled to a mass detector (Agilent 5975C) using a polyethylene glycol column (ZB-Wax) with 30 m length × 0.25 mm internal diameter × 0.25 μm film thickness. Carrier gas was Helium (He) and the injection flow was 1 mL min^{-1} split 1:10. The column's initial temperature was set to 50°C, held for 2 min, and then raised to 220°C at a rate of 4°C min^{-1} and held for 7 min, totalizing 51.5 min. The injector temperature and transfer line between GC and MS was 250°C. The data acquisition system was performed by GC-MS and the data analysis by software with database NIST MS Search version 2.0.

Sensory analyses

Between the 1st and 6th lumbar vertebrae, the collected samples were used for sensory analyses. The meat samples were thawed for 24 hours at 4°C. Next, they were cooked on a grill plate pre-heated at a temperature of 170 until reaching 70°C in the geometric center, which was monitored by a thermometer with a digital reader. When the pre-set temperature was reached, samples were taken off the grill, brick-shaped cuts measuring 1.0 × 1.0 × 3.0 cm were made later according to the fiber orientation, wrapped in aluminum paper and identified with a single random three-digit code. Samples were kept warm at 70°C until serving within 10 min after cooking. The thickness of subcutaneous fat has been removed when samples were taken to test.

Sensory analyses performed according to the methodology recommended by Campo (2005) to consumers untrained. A total of 70 untrained testers who enjoy lamb meat were invited to participate during the 10th Lamb Festival on Farming Exhibition Centre to be representative in the city of Maringá, Paraná State. The tests were performed in individual booths, with natural light and temperature, from 10 AM until noon.

The untrained testers were instructed to how to do the test and, if there still any doubts ask for clarification. Each tester was served a sample of meat from each treatment in a disposable container at the same time. The evaluation form was delivered along with the meat samples, and the order of receipt was switched to each taster, to minimize the effect that the order of the samples can exercise. To remove any residual taste in between samples, mineral water at room temperature and unsalted crackers were offered.

The following attributes were evaluated: odor characteristic to the species, flavor characteristic to the species, succulence, and overall acceptance, through a questionnaire with an eight-point hedonic scale, divided as low intensity (1- extremely un-; 2- very un-; 3- moderately un-; 4- slightly un-) and high intensity (5- slightly; 6- moderately; 7- very; 8- extremely).

Regarding the profile of the panel of consumers, most (70%) aged from 18 to 35 years, and only 30% were from 36 to 55 years old. Regarding their gender, 58.57% of them were male and 41.43% female. The education level among the evaluators was considered high, since 75.71% of them had a college degree, 20% completed high school, and only 4.29% had only completed primary education.

Statistical analysis

The statistical analysis was performed on the Statistical Analysis System - SAS. The experimental design was completely randomized, with three treatments and eight replicates, considering the different SFT at slaughter (2.00, 3.00 and 4.00 mm). Means were compared by Tukey's test at 5% significance.

Results and discussion

Mean body weight at slaughter according to SFT and days on feedlot were 20.64 kg and 34 days for lambs slaughtered with 2.0 mm (n = 8); 26.77 kg and 84 days for lambs slaughtered with 3.0 mm (n = 8); and 32.12 kg and 111 days for lambs slaughtered with 4.0 mm (n = 8).

The same experiment data can help understand the results of this work. Carcasses of Pantaneiro lambs were used to evaluate the physiological maturity. The results showed that the lambs reached such physiological maturity from slaughter with 3.0 mm of SFT (Mora et al., 2014).

The concentrations of total lipid of the treatments were: 2.79 g 100 g^{-1} for Pantaneiro lambs slaughtered with 2.00 mm SFT, 3.76 and 4.84 g 100 g^{-1} for lambs slaughtered with 3.00 and 4.00 mm SFT respectively.

The subcutaneous fat thickness had no effect on the fatty acid profiles, shown in Table 2. According to Díaz et al. (2005), the fatty acid profile of sheep meat is affected by diet, age, sex and breed. The fact that the lambs were fed the same diet and showed homogeneity for age, and their same origin, explains the absence of differences.

Table 2. Detailed fatty acid profile of the *Longissimus dorsi* muscle from lambs slaughtered with different subcutaneous fat thicknesses.

Fatty acid	Subcutaneous fat thickness (mm)			CV%
(g 100 g^{-1} TFA[1])	2.00	3.00	4.00	
C 10:0 (capric)	0.15a	0.17a	0.16a	15.58
C 12:0 (lauric)	0.13a	0.11a	0.11a	28.71
C 14:0 (myristic)	3.50a	3.37a	3.55 a	19.67
C 16:0 (palmitic)	25.86a	26.53a	26.40a	6.33
C 16:1*c9* (palmitoleic)	1.75a	2.24a	1.85a	13.43
C 18:0 (stearic)	15.14a	14.93a	14.79a	12.71
C 18:1*n-9t* (elaidic)	2.12a	2.30a	2.34a	25.90
C 18:1*n-9* (oleic)	38.30a	38.05a	38.48a	4.37
C 18:2*n-6* (linoleic)	3.05a	2.77a	3.01a	18.67
C 18:2*c9-t11*(CLA)[2]	0.48a	0.42a	0.51a	15.85
C 18:3*n-3* (linolenic)	0.40a	0.36a	0.34a	26.19
C 20:4 (arachidonic)	0.58a	0.50a	0.56a	25.26
Others	8.39a	8.36a	8.40a	26.64
SFA[3]	44.78a	45.11a	45.01a	5.58
MUFA[4]	42.00a	42.59a	42.67a	5.20
PUFA[5]	4.51a	4.05a	4.42a	22.01
Total UFA[6]	46.51a	46.64a	47.09a	26.02
PUFA/SFA	0.10a	0.09a	0.10a	47.21

[1]TFA = total fatty acids; [2]CLA = conjugated linoleic acid. [3]SFA = saturated fatty acids; [4]MUFA = monounsaturated fatty acids; [5]PUFA = polyunsaturated fatty acids; [6]UFA = unsaturated fatty acids. Means followed by the same letters in the rows indicate that there were no differences by Tukey's test (p > 0.05).

Capric acid (C10:0) is transformed into the body monocaprin, a compound with antiviral and antimicrobial properties, important for human health (Costa et al., 2012).The average of this acid found between treatments was 0.16 g 100 g^{-1}.

High levels of saturated fatty acids of shorter length as C12:0, C14:0 and C16:0 considered hypercholesterolemic. If found at high levels in the plasma they will provide a cholesterol concentration (Willians, 2000) in the bloodstream, especially of oxidized particles of low-density lipoproteins (LDL), which are associated with atherosclerosis, the main cardio-vascular disease (CVD).

A detailed study of the fatty acid profile of the meat is essential rather broad classifications of lipids with respect to subsequent impacts on serum cholesterol, and should therefore be considered when making dietary recommendations for the prevention of CVD (Daley, Abbott, Doyle, Nader, & Larson, 2010).

Among the analyzed SFA, lauric acid (C12:0) had an average of 0.12 g 100 g^{-1} and myristic acid (C14:0) with 3.48 g 100 g^{-1} between treatments.

Palmitic acid (C16:0) showed a high rate, averaging 26.17 g 100 g^{-1}. Leão et al. (2011) found concentration of palmitic acid (26.41%) similar in of meat from lambs finished on feedlot with two roughage: concentrate ratios.

Stearic acid (C18:0) is considered a neutral acid (averaging 14.93 g 100 g^{-1}), because, according to Willians (2000), it does not cause any change in the cholesterol concentration in the bloodstream. This acid is rapidly denatured and converted to oleic acid by the organism after its ingestion (Bressan, Prado, Pérez, Lemos, & Bonagurio, 2001), like palmitic acid, transformed into palmitoleic acid (C16:1*c9*) with concentration of 1.95 g 100 g^{-1} in this study.

Elaidic acid (C18:1*n-9t*) is classified as a synthetic fatty acid, and has also been associated with increased risk of cardiovascular disease (Valsta, Tapanainen, & Mannisto, 2005). The meat of Pantaneiro lambs presented concentration 2.09 g 100 g^{-1} of this acid.

Oleic acid (18:1*n-9*) was the acid found at the highest quantity in the lambs' meat, regardless of their SFT (38.30 g 100 g^{-1}), as was also found in the studies of Arruda et al. (2012). According to Sañudo et al. (2000), ruminants present high concentrations of oleic acid in their intramuscular fat composition.

The SFT did not affect the concentration of PUFA, mean values were as follows: 2.94 linoleic (18:2*n-6*), 0.47 CLA (18:2*c9-t11*), 0.37 linolenic (18:3*n-3*) and 0.55 g 100 g^{-1} arachidonic (20:4).

According to Menezes et al. (2009), the linoleic and linolenic acids have a beneficial effect, because they are precursors of eicosanoid hormones and are part of the phospholipids of the membrane.

The conjugated linoleic acid CLA is formed by rumen biohydrogenation of intermediate linoleic acid (Lee, 2013) and if the biohydrogenation is not complete, it may be absorbed by the gut epithelium and will be part of the animal fat (Ladeira &

Oliveira, 2007). CLA are beneficial to human health (Park, 2009) and it is indicated on the power to be good oxidant, to contribute to cancer prevention, decreased atherosclerosis, improved immune response, diabetes and cholesterol control (Schmid, Collomb, Sieber, & Bee, 2006). The CLA are present at higher concentrations in ruminant products than in corresponding meats from non-ruminants or in vegetable oils (Lawson, Moss, & Givens, 2001), because they are formed in the rumen from dietary linoleic acid.

However, high levels of PUFA may produce alterations in the meat flavor, due to its susceptibility of oxidation and to the production of anomalous volatile components during cooking (Wood et al., 1999).

The fatty acids obtained in the meat of the Pantaneiro lambs, whose mean values were 44.97 for SFA, 42.42 for MUFA, and 4.34 g 100 g^{-1} for PUFA were very different from the fatty acid composition of the diet (SFA = 28.72; MUFA = 34.08; and PUFA = 37.20 g 100 g^{-1}) ingested during the experimental period.

Red meats, such as lamb, contain similar proportions of monounsaturated fatty acids to saturated fatty acids, and small amounts of polyunsaturated fatty acids (Wyness et al., 2011).

According to Jenkins, Wallace, Moate, and Mosley (2008), lipids are extensively altered in the rumen, resulting in marked differences between the fatty acid profile of lipids in the diet (mostly unsaturated fatty acids) and lipids leaving the rumen (mostly SFA). Ruminal microbes transform lipids entering the rumen via 2 major processes, lipolysis and BH. The first transformation is lipolysis, the hydrolysis of the ester linkages releasing free fatty acid (Kim, Huws, Lee, & Scollan, 2009).

The biohydrogenation is a natural mechanism, directed by rumen microorganisms, which is to reduce the deleterious effect of lipids (Valinote, Nogueira Filho, Leme, Silva, & Cunha, 2005), promoting saturation unsaturated fatty acids putting hydrogen in the carbon chain leaving only single bonds. This is because diets containing high levels of PUFA cause toxicity to microorganisms especially to Gram-positive bacteria and protozoa, which adhere to the food particles by creating a physical barrier to the action of microorganisms and microbial enzymes (Jenkins, 1993). As a result of this process, the SFA class is absorbed by the intestine and incorporated into the muscle tissue (Costa, Cartaxo, Santos, & Queiroga, 2008).

The average 46.75 g 100 g^{-1} indicates the predominance of unsaturated fatty acids (UFA) against 44.97 g 100 g^{-1} SFA in the sheep meat in this

experiment. A possible explanation for the greater concentration of UFA may be the fact that the diet contains 70% concentrate, which contributes to reduction of the rumen pH, which reduces the biohydrogenation and promotes the absorption of UFA in the post-rumen. Higher passage rates in diets used in confinement may also increase the escape of UFA from the rumen (Jenkins, Wallace, Moate, & Mosley, 2008).

Fatty acid metabolism in the rumen has a major influence on the fatty acid composition of ruminant meats and milk (Jenkins et al., 2008). This is one of the reasons why sheep meat is characterized by a high concentration of SFA and a low PUFA/SFA ratio (Cooper et al., 2004)

This ratio in the human diet is important to reduce the risk of cardiovascular diseases (Costa et al., 2009). The PUFA/SFA ratio of 0.4 is recommended for a healthy diet with the consumption of meat, but has caused a negative impact on lamb meat. Lower values were described by Banskalieva, Sahlu, and Goetsch (2000) in sheep meat, which ranged from 0.07 to 0.26 which is an outcome attributed mainly to the biohydrogenation of dietary UFA by the rumen microorganisms. Although 0.1 is considered a low ratio, this value was found in the present study.

The results of the sensory analysis by the consumers can be viewed in Table 3. The meat from the animals slaughtered with 4.00 mm SFT received the best score for the variables flavor characteristic to the species and overall acceptance as compared with the lambs slaughtered with 2.00 mm SFT, which demonstrates the consumers' ability to identify sheep meat.

Table 3. Mean values for the sensory analysis of Pantaneiro lambs slaughtered with different subcutaneous fat thicknesses.

Attribute	Subcutaneous fat thickness (mm)			CV%
	2.00	3.00	4.00	
Flavor	6.76b ± 1.73	7.14ab ± 1.68	7.49a ± 1.29	22.17
Odor	6.91a ± 1.61	7.17a ± 1.69	7.40a ± 1.30	21.58
Juiciness	7.36a ± 1.27	7.57a ± 1.69	7.62a ± 1.40	19.47
Overall acceptance	6.73b ± 1.64	7.17ab ± 1.61	7.47a ± 1.07	20.59

Same letter within the same row indicates no significant difference (Tukey, 5%).

Even the testers appreciate the meat without subcutaneous fat, yet, the higher concentration of total lipids in the muscle seems to have influenced their overall acceptance and flavor.

Madruga, Narain, and Costa (2002) report that odor and flavor are directly related to the fat content in the muscle. The treatment with 3.00, however, did not differ from the others. Nevertheless, with these scores, it can be affirmed, by the hedonic scale, that meat was classified as slightly to extremely accepted by the consumers in these attributes. The

results can be explained by cultural questions, such as the form of preparation, with which these consumers are not accustomed.

For the sensory traits odor and juiciness, no effect of SFT was observed. The mean values obtained for characteristic odor (7.16) and juiciness (7.52) characterize the Pantaneiro genetic group as producers of very appreciable meat by consumers.

Conclusion

The SFT did not alter the fatty acid profile of the meat from Pantaneiro lambs. The meat of lambs slaughtered with 3.00 and 4.00 mm SFT were very accepted by consumers. Therefore, it is recommended to slaughter lambs with 3.00 mm thickness of subcutaneous fat on the loin, because consisted better number of favorable attributes in sensory analysis.

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