Preliminary Study on Meat Quality of
Goats Fed Levels of Licury Oil in the Diet*

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ABSTRACT : The study aimed to evaluate the best level of licury oil in the diet of 3/4 Boer goats, as determined by profile analysis of commercial cuts on aspects of chemical composition, sensorial quality and fatty acid content. Nineteen male goats were used, with an initial weight of 10.8 kg/live weigh. The animals were fed with hay and a concentrated mix containing different levels of licury oil, which constituted the treatments. The experiment lasted for 60 days, at which point the animals were submitted to feed fasting and slaughtered. The carcass weight, commercial yield and cuts were measured. The ham was collected for sensorial and chemical evaluation and the *longissimus dorsi* was collected for fatty acid profile analysis. The addition of licury oil to the diet did not promote changes in the proportions and weights of the commercial cuts, nor to the meat's sensorial attributes. The sum of medium-chain fatty acids and the atherogenicity index was increased with the addition of oil. Licury oil can be added to the diet of goats (up to 4.5%) without resulting in changes in to the proportions of the commercial cuts, or to the chemical composition or sensorial characteristics of the meat. Based on the chain length of fatty acids, the addition of 4.5% licury oil can improve the quality of meat, but no effect was noted in relation to the atherogenicity index. (**Key Words :** Fatty Acids, Kids, Lipids, Licury Oil, Ruminants)

INTRODUCTION

The importance of raising meat goats in Brazilian livestock is increasing, due to increased demand in terms of goat meat consumption (Carvalho Júnior et al., 2009; Costa et al., 2010). The characteristics of this meat have a strong appeal for the consumer market that increasingly demands healthy food, since it has a low fat content compared to other red meats (Kannan et al., 2003).

Besides the chemical composition of meat, the sensory

characteristics are fundamental for the development of this product, because the degree of acceptability by the consumer depends mainly on the appearance, odour, flavour and texture of the meat (Madruga et al., 2005). However, some authors claim that goat meat is disliked due to its distinct odour and taste, typical of animals slaughtered older (Intarapichet et al., 1994).

Despite the low lipid content in this meat compared to meat from other ruminants, goat meat has a high proportion of unsaturated fatty acids in addition to being a source of conjugated linoleic acid (Webb et al., 2005). These compounds have beneficial effects on human health as anti-inflammatory, anti-thrombotic and atherosclerotic preventatives (Givens et al., 2006).

Several factors can affect the quality characteristics of goat meat such as slaughter age, breed, castration, nutrition and butchering methods (Tshabalala et al., 2003; Costa et al., 2008). Among these, nutrition is predominant, because changes in animal diets may improve both the quantity and quality of the final product (Johnson and McGowan, 1998; Geay et al., 2001).

The addition of lipids to ruminant feed is a tool used

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when an increase in the energy density of the diet is desired without increasing the proportion of grains as a source of starch, since these foods represent a more expensive fraction of the diet. Dutta et al. (2008) Marinova et al. (2001) and Mir et al. (2000) reported that the use of vegetable oils in ruminant feed may increase the concentration of unsaturated fatty acids and conjugated linoleic acid in muscle, in addition to influencing fat deposition in tissues and consequently changing the chemical and sensorial characteristics of meat.

Various oils have been tested in ruminant feed, and although licury oil is little known as an animal feed additive, its use is common in the manufacture of cosmetics and soap products. This oil is obtained from the fruit of the palm (*Syagrus coronata* (Martius) Beccari) native to the semiarid region of northeastern Brazil. The collection and marketing of this fruit are an important source of income for the population of the region (Borja et al., 2010).

This research was conducted with the purpose of determining the best level of licury oil in the diet of 3/4 Boer goats in relation to chemical composition, sensory characteristics and fatty acid profile of the meat.

MATERIAL AND METHODS

The experiment was conducted in the School of Veterinary Medicine, Federal University of Bahia in Salvador, Bahia, from October to December 2007. We used 19 3/4 Boer goats, intact, vaccinated and dewormed, at an average age of 90 days and an initial weight of 10.8±2.00 kg. The animals were housed individually in pens measuring 1.0×1.0 m, with suspended wooden floors, and were provided with water troughs and feeders.

The experiment lasted 60 days and was preceded by 15 days of animal adaptation to the environment, management and diets. The kids were fed twice daily with. The concentrate was composed of corn meal, soybean meal, minerals and licury oil. The chemical composition of the

ingredients is provided in Table 1. The proportion of ingredients calculated for the diets were isonitrogen, and licury oil was added to the diet at levels of 0.0, 1.5, 3.0 and 4.5% of dry matter (Table 2).

The chemical composition of the ingredients of the diet was determined according to AOAC (1990) for the analysis of dry matter (DM), ash (AS), crude protein (CP) and ether extract (EE). The analysis for the determination of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were done according to Van Soest et al. (1991). The non-fibrous carbohydrates were calculated according to Mertens (1997). For the extraction of fatty acids present in the ingredients for later analysis using a gas chromatograph, the methodology described by Rodríguez-Ruiz et al. (1998) was used. The chemical composition and fatty acid profiles are shown in Table 2.

Five animals were used for each treatment, except for the group treated with 4.5% oil, in which four animals were used, since one animal died at the end of the adaptation period. The roughage used Tifton-85 hay (*Cynodon sp.*) ground into particles of about 5 cm. The food presentation was made to ensure between 10% and 20% remained. The water supply was *ad libitum*.

At the end of the experiment, the animals were slaughtered (after fasting for 12 h) at approximately 13.15±2.5 kg body weight and five months of age. After slaughter, they were skinned and eviscerated. The carcasses were kept in the cold (4°C) for 24 hours and then the *longissimus dorsi* and ham (the section between the last lumbar vertebrae and first sacral) were collected, according to the methodology adapted by Colomer-Rocher (1987). This last cut (one per animal) was used for chemical and sensory analysis.

We collected several fragments of the leg muscles (biceps femoris, semitendinosus, adductor, semimembranosus and quadriceps), which were finely minced and homogenized in a multiprocessor. Five grams of this material was diluted in 100 ml of distilled water until they

Table 1. Chemical composition of ingredients in diets fed to 3/4 Boer goats

Composition	Contents			
	Corn	Soya bean meal	Tifton 85 hay	Licury oil
Dry matter (%)	88.91	88.51	89.64	100.00
Ash (% DM)	1.54	6.51	6.51	-
Crude protein (% DM)	5.88	42.92	6.16	-
Ether extract (% DM)	5.41	3.52	2.12	100.00
Neutral detergent fibre (% DM)	11.84	10.76	75.63	-
Acid detergent fibre (% DM)	4.44	8.05	44.26	-
Lignin (% DMS)	1.63	0.39	7.39	-
Cellulose (% DM)	2.81	7.66	16.87	-
Hemicellulose (% DM)	7.40	2.71	31.38	-
Non-fibre carbohydrates (% DM)	75.34	36.29	9.58	-

Table 2. Proportion of contents, chemical composition and fatty acid profile of experimental diets fed to 3/4 Boer goats

Contents (% DM)	Licury oil (% DM)			
	0.00	1.50	3.00	4.50
Corn meal	34.12	32.30	30.40	28.70
Soy meal	13.28	13.60	14.00	14.20
Licury oil	0.00	1.50	3.00	4.50
Premixed mineral[1]	2.60	2.60	2.60	2.60
Tifton-85	50.00	50.00	50.00	50.00
Chemical composition (% DM)				
Dry matter	89.52	89.68	89.84	90.01
Ash	7.54	7.53	7.53	7.53
Crude protein	10.79	10.81	10.87	10.86
Ether extract	3.37	4.78	6.20	7.61
Neutral detergent fibre	43.29	43.10	42.92	42.74
Acid detergent fibre	24.71	24.66	24.61	24.55
Lignin	4.30	4.27	4.24	4.22
Cellulose	35.03	33.77	32.48	31.47
Hemicellulose	67.40	69.30	75.30	80.60
Fatty acid profile (% total of fatty acids)				
C12:0	0.31	1.73	3.14	4.56
C14:0	0.13	0.60	1.08	1.55
C16:0	15.73	15.55	15.38	15.19
C18:0	2.64	2.71	2.79	2.87
Other saturated fatty acids	0.95	1.55	2.16	2.76
C18:1 n-9	27.21	26.01	24.77	23.57
C18:2 n-6	48.23	46.72	45.21	43.69
C18:3 n-3	2.16	2.15	2.14	2.13
Other non-saturated fatty acids	2.63	2.98	3.34	3.68
MCFA[2]	17.21	19.53	21.85	24.16
LCFA[3]	82.79	80.47	78.15	75.84

[1] Assurance levels (per kg in active elements): 120.00 g calcium, 87.00 g phosphorus, 147.00 g sodium, 18.00 g sulphur, 590.00 mg copper, 40.00 mg cobalt, 20.00 mg chromium; 1800.00 mg iron, 80.00 mg iodine; 1,300.00 mg manganese, 15.00 mg selenium; 3,800.00 mg zinc, 300.00 mg molybdenum; maximum 870.00 mg fluoride.
[2] Medium-chain fatty acids (11 to 16 carbons). [3] Long-chain fatty acids (over 16 carbons).

were completely dissolved and the pH was taken with a digital probe (Dias et al., 2008). The rest of the ground material was stored and frozen for subsequent chemical analysis. The chemical analyses were performed to determine the moisture content, ashes, CP and EE.

For sensory evaluation, ham muscles surrounding the femur (biceps femoris, semitendinosus, adductor, semimembranosus and quadriceps) were dissected and diced into fragments of about 3 cm by 3 cm and grouped by treatment. Salt was added to the fragments at a concentration of 0.75% (by weight of the meat, which were put into a baking dish, covered with aluminium foil and placed in a preheated oven (200°C) until the internal temperature reached 75°C. The meat was then transferred to a container in a hot water bath until the time of sensory evaluation. Sensory analysis was performed with the participation of 51 panellists. Panellists were randomly

selected, informed on what parameters to evaluate and how to make a score of the attributes. The samples were assessed for appearance, odour, flavour, tenderness and juiciness, and each parameter was scored using a hedonic scale of 1 to 9 such that 1 referred to a less favourable condition and 9 represented a more favourable condition. Panellists made the evaluation in individual booths, where they received two pieces of meat from each treatment. To remove the aftertaste from the samples, room temperature mineral water was used.

Fatty acids were extracted from the meat using methods described by Hara and Radin (1978). After extraction and methylation, each sample was injected (1 ml) into the gas chromatograph (model Finnigan Focus GC) with a flame ionization detector, a capillary column CP-Sil 88 (Varian; 100 m long and 0.25 µm internal diameter) and a 0.20 µm thick film. Hydrogen was used as the carrier gas at a flow

Table 3. Chemical composition and pH of the leg muscles[1] of 3/4 Boer goats fed diets with levels of licury oil

Item	Level of licury oil (%)				SEM[2]	Regression equation
	0.00	1.50	3.00	4.50		
	(n 5)	(n 5)	(n 5)	(n 4)		
Crude protein (%)	19.48	20.86	20.53	20.08	0.45	$\hat{Y} = 20.24$
Ash (%)	1.07	1.04	1.08	1.00	0.04	$\hat{Y} = 1.05$
pH	6.57	6.68	6.67	6.72	0.13	$\hat{Y} = 6.66$

[1] *Biceps femoris, semitendinosus, adductor, semimembranosus* and *quadriceps*. [2] Standard error of the mean.

rate of 1.8 ml/min. The programme was an initial oven temperature of 70°C, with a waiting time of 4 min at 175°C (13°C/min), a waiting time of 27 min at 215°C (4°C/min), a waiting time of 9 min, then an increase of 7°C/min up to 230°C for 5 minutes, totalling 65 min. The vaporiser temperature was 250°C and the detector was 300°C. The identification of fatty acids was by comparison of retention times of methyl esters of the samples with a predefined pattern which were then quantified by normalising the areas of methyl esters. The results are expressed as area percentage (%). From the fatty acid profile, we calculated the atherogenicity index (IA), a parameter was proposed by Ulbricht and Southgate (1991) which has a positive correlation with the risk of cardiovascular disorders. The calculation is as follows: $AI = [C12:0+(C14:0\times4)+C16:0]/(\text{Total unsaturated fatty acids})$. We also calculated the relative proportions of total saturated fatty acids (Sat) and unsaturated (Insat) and omega-6 fatty acids (n-6) and omega-3 (n-3). The experimental design was randomised and data were evaluated by analysis of variance and regression tests (with a 5% significance level) using SAS® 9.1.3 software.

RESULTS AND DISCUSSION

The CP of beef based on natural matter did not differ between treatments (Table 3), and the concentration of this nutrient in meat was relatively stable. Geay et al. (2001) previously reported that the CP content in ruminant meat varies between 17% and 22% of natural matter. Sheridan et al. (2003), in evaluating different energy levels in the diet of Boer goats, also found no differences in the crude protein content of meat. Lee et al. (2008) found similar values, after assessing meat composition from goats fed with different diets after weaning.

The ash content in the meat did not differ between treatments (Table 3), possibly because the samples were from animals of a similar age. Bezerra et al. (2000), Madruga et al. (2005), Freitas et al. (2011) and Hashimoto et al. (2007) observed values close to the present study. These authors assessed the composition of meat in relation to genetic group, type of cut and diet and found no variation in ash content between the different experimental groups.

The pH did not vary between treatments. According to Geay et al. (2001) the pH of meat is strongly influenced by muscle glycogen stores at slaughter and the rate of cooling of the meat. This fact explains the similarity in pH between treatments, because all animals were subjected to the same period of pre-slaughter fasting (which determines the concentration of glycogen stores) and the same post-slaughter procedures.

These pH values can be considered high, as Webb et al. (2005) reported that most values for goat meat are between pH 5.6 and pH 6.2. However Madruga et al. (1999) and Madruga et al. (2002) reported values close to the present study slaughtered animals of a similar age (175 days). These authors noted that younger animals slaughtered has meat with higher pH. Another factor that justifies the high pH values reported here compared to the literature is the muscle used to measure this parameter, because most studies have used the *longissimus dorsi*, and Madruga et al. (2005) and Kadim et al. (2003) have found that the meat from the leg muscles has a higher pH compared to the *longissimus dorsi*. Kadim et al. (2003) also argue that this difference may be associated with the different proportions of red and white muscle fibers between muscles, as this interferes with muscle metabolism before death and in involved in the post-mortem decrease in pH.

The moisture content of the meat varied by a quadratic trend in relation to the addition of oil in the diet (Figure 1), such that the moisture content decreased by 75.7% with the addition of 2.46% oil to the diet. Several authors have mentioned that moisture has an inverse relationship on the fat content of meat (Sheridan et al., 2003; Madruga et al., 2005; Lee et al., 2008; Santos et al., 2008). In this study, the fat content was influenced by the addition of oil (p = 0.15), inversely to moisture (Figure 1). The quadratic trend of fat content in meat was probably related to the consumption of TDN ($\hat{Y} = 79.10+77.68X-13.7X^2$) by these animals, which was similar to the trend for the fat content in the meat.

Regarding the sensory evaluation, no differences were found between the treatments in terms of their sensory attributes (Table 4). This was probably related to the similarity of the chemical composition of meat between the treatments. The average score of the appearance (Table 4) was lower than that described by Madruga et al. (2005) and Dias et al. (2008). According Kadim et al. (2003) and
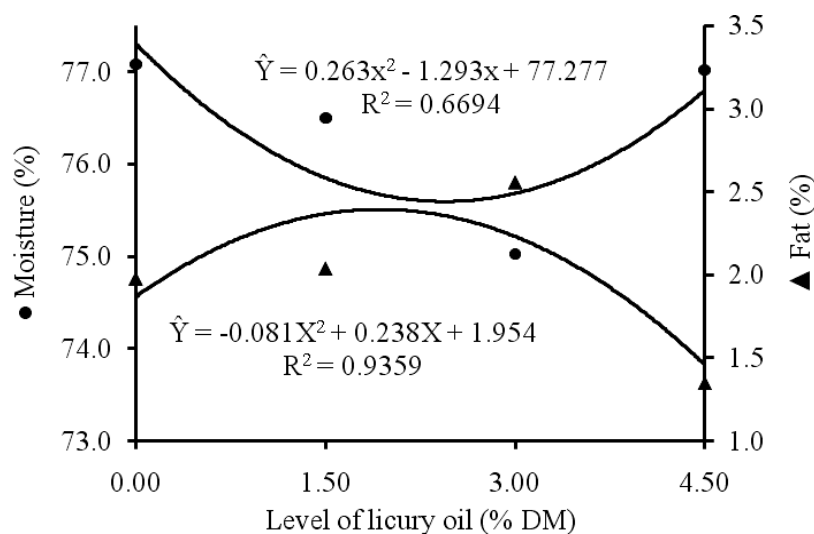
$$\hat{Y} = 0.263x^2 - 1.293x + 77.277$$
$$R^2 = 0.6694$$

$$\hat{Y} = -0.081X^2 + 0.238X + 1.954$$
$$R^2 = 0.9359$$

Figure 1. Moisture content (●) and fat (▲) of leg muscles of 3/4 Boer goats fed diets with levels of licury oil.

Madruga et al. (2005), high pH values (as in this work) can offer darker meat and Dias et al. (2008) have mentioned that the colour of goat meat has less acceptance because consumers associate dark meat with meat taken from older animals.

Licury oil in the diet did not influence the aroma or flavour of the meat, indicating that changes in the concentration of fat or the fatty acid profile did not affect these parameters. The scores for tenderness and meat taste were close to those described by Madruga et al. (2002), who evaluated differences between intact and castrated goats, and Dhanda et al. (2003) who evaluated goats slaughtered at 93 days old.

The classification of tenderness was higher (Table 4) than what was described by Dias et al. (2008) who assessed the meat of animals slaughtered between six and seven months of age. Madruga et al. (2002) reported a value close to the one reported in this work for the meat of animals slaughtered at 175 days of age. These same authors found that meat from animals slaughtered at a later age was less tender. The high meat tenderness in this study can be attributed to the age at slaughter of the animals (150 days), because with advancing age, the texture of meat changes

due to the increased stability of collagen caused by the presence of cross-bridges between these molecules (Hedrick et al., 1994).

The variation in moisture content of meat (Figure 1) could reflect changes in its succulence; however, this feature does not depend solely on the amount of water in meat. According Geay et al. (2001) and Webb et al. (2005), juiciness is influenced by the moisture and intramuscular fat of meat in addition to the saliva produced during tasting, so attributes that stimulate salivation (appearance, aroma and flavour) can also interfere with the determination of juiciness.

Regarding the fatty acid profile, the addition of licury oil increased the concentration of C12:0 and C14:0 in animal diets (Table 1), and this was reflected in the increase of these fatty acids in the flesh of animals (Table 5). According to Desai et al. (2008) and Chardigny et al. (2008), these fatty acids together with palmitic acid (C16:0) are the major atherogenic fatty acids. Chardigny et al. (2008) reported that products from palm trees (like licury oil) are rich in lauric acid (C12:0) and myristic acid (C14:0).

The increase in the concentration of C17:0 *iso* (Table 5) may be related to the availability of protein in the rumen,

Table 4. Sensory attributes of 3/4 Boer goat meat[1] fed diets with levels of licury oil

Variables[2]	Level of licury oil (%)				SEM[3]	Regression equation
	0.00	1.50	3.00	4.50		
Appearance	6.47	7.00	6.67	7.00	0.23	$\hat{Y}= 6.78$
Aroma	6.65	6.43	6.39	6.37	0.21	$\hat{Y}= 6.46$
Flavor	6.88	6.73	6.73	6.62	0.26	$\hat{Y}= 6.74$
Tenderness	7.78	7.67	7.63	7.44	0.19	$\hat{Y}= 7.63$
Juiciness	6.25	6.65	6.49	6.76	0.22	$\hat{Y}= 6.54$

[1] The leg muscles (*biceps femoris, semitendinosus, adductor, semimembranosus* and *quadriceps*) was used for analysis.
[2] Hedonic Scale from 1 to 9. [3] Standard error of the mean.

Table 5. Fatty acids as percentage of total fatty acids in *longissimus dorsi* of 3/4 Boer goats fed diets with levels of licury oil

Iten	Level of licury oil (%)				SEM[1]	Regression equation	R[2]
	0.00	1.50	3.00	4.50			
C 10:0	0.14	0.13	0.12	0.15	0.01	$\hat{Y}= 0.13$	-
C 12:0	0.12	0.29	0.56	0.68	0.13	$\hat{Y}=0.47*X - 2.27*$	0.56
C 14:0	1.96	3.24	4.72	4.82	0.69	$\hat{Y}=0.89X + 1.97$	0.54
C 15:0	0.76	0.92	1.04	1.01	0.13	$\hat{Y}= 0.93$	-
C 16:0	23.68	23.44	23.19	24.34	0.62	$\hat{Y}= 23.66$	-
C 17:0 Iso	0.39	0.40	0.47	0.45	0.03	$\hat{Y}=0.03X + 0.37$	0.45
C 17:0	1.23	1.06	1.33	1.11	0.09	$\hat{Y}= 1.18$	-
C 18:0	17.68	15.43	18.83	16.77	1.47	$\hat{Y}= 17.18$	-
C 16:1 C9	2.57	2.73	2.67	2.68	0.21	$\hat{Y}= 2.66$	-
C 18:1	39.70	41.05	37.14	37.55	2.48	$\hat{Y}= 38.86$	-
C 22:1	3.04	3.20	2.47	2.56	1.04	$\hat{Y}= 2.82$	-
C 18:2	4.46	3.61	2.98	3.31	0.62	$\hat{Y}= 3.59$	-
C 18:3 n3	0.16	0.15	0.08	0.15	0.03	$\hat{Y}= 0.13$	-
CLA	0.31	0.28	0.19	0.18	0.04	$\hat{Y}= 0.24$	-
C 20:5	0.64	0.59	0.61	0.47	0.24	$\hat{Y}= 0.58$	-
Outros	2.79	3.48	3.37	3.77	0.38	$\hat{Y}= 3.35$	-
Insat	53.64	54.51	48.89	49.87	2.32	$\hat{Y}= 51.73$	-
Sat	46.36	45.49	51.11	50.13	2.32	$\hat{Y}= 48.27$	-
Sat:Insat	0.88	0.84	1.10	1.01	0.09	$\hat{Y}= 0.96$	-
AI[2]	0.60	0.68	0.92	0.90	0.10	$\hat{Y}=0.11X + 0.56$	0.33
n-6 : n-3	8.39	6.26	4.85	6.37	1.44	$\hat{Y}= 6.47$	-
n-6	4.46	3.62	2.99	3.33	0.50	$\hat{Y}= 3.60$	-
n-3	0.17	0.16	0.11	0.15	0.03	$\hat{Y}= 0.15$	-
MCFA[3]	29.35	30.90	32.43	33.69	1.29	$\hat{Y}= 0.97X + 29.4$	-
LCFA[4]	70.36	68.65	66.76	65.45	1.42	$\hat{Y}= -1.12X +70.31$	-

[1] Standard error of mean. [2] Atherogenicity index. [3] Medium-chain fatty acids (11 to 16 carbons). [4] Long-chain fatty acids (over 16 carbons).
* Values subject to logarithmic transformation.

because there was an increase in protein digestibility with the addition of licury oil ($\hat{Y} = 60.41+4.064X$). The branched odd chain fatty acids (such as 17:0 iso) are synthesised by rumen microorganisms which use amino acids as a carbon source for the synthesis of fatty acids (Kaneda, 1991). Therefore, the increase in protein digestibility increased the substrate availability for microorganisms that synthesised C17:0 *iso*, a fact that favoured greater incorporation of fatty acids in the meat of these animals. This increase in C17:0 *iso* could compromise the sensorial quality of meat, because Rousset-Akrim et al. (1997) and Young et al. (1997) reported that branched-chain fatty acids are related to "rancidity" in sheep meat. However, the increase of C17:0 *iso* was not associated with a change in the flavour or taste of the meat in this study (Table 4).

The addition of licury oil tended (p = 0.093) to reduce the content of CLA (C 18:2 cis-9 trans-11), which can be explained by the fact that CLA is synthesised in the rumen as an intermediate of the biohydrogenation process of linoleic acid (C18:2 n9). With the addition of licury oil to the animals' diet, there was a decrease in the linoleic acid

content of the meat (Table 1).

The increased levels of C12:0 and C14:0 without an increasing in the total saturated fatty acid content provided an increase in AI (Table 5), and according to Hu et al. (2001) these acids are crucial for high levels of LDL cholesterol and the blood plasma in humans. Therefore, an increase in this parameter is directly related to the risk of cardiovascular disease. Despite the addition of licury oil to promote an increase in this parameter, all values found were lower than those described by Silva (2005) who evaluated the effect of lipid supplementation on goat milk quality.

Regarding chain size, licury oil in animal diets provided a reduction in the average length of fatty acids in the meat. The medium-chain fatty acids increased as the long chain fatty acids decreased (Table 5). This behaviour can be explained by an increase in the proportion of MCFA and a reduction in LCFA with the addition of licury oil (Table 1). Regarding the quality of the meat, this change was beneficial, because the smaller chain length fatty acids are the most digestible (Jansen et al., 1986). Acids of short and medium chains and branched chains are related to the

"rancid" aroma of meat according to Rousset-Akrim et al. (1997) and Young et al. (1997). However, the reduction in chain size did not affect the sensorial and quality parameters of the meat (Table 4).

CONCLUSION

Licury oil can be used up to 4.5% in the diet of 3/4 Boer goats without significantly interfering in the proportion of commercial cuts, chemical composition and sensorial characteristics of the meat. Based on long-chain fatty acid content in the meat, adding 4.5% can improve the quality of the meat of animals, but no relation to the atherogenicity index was determined.

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