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Effect of cassava wastewater on physicochemical characteristics and fatty acids composition of meat from feedlot-finished lambs

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ABSTRACT. This study aimed to evaluate the effects of includingcassava wastewater (0.0, 0.5, 1.0, or 1.5 L animal^{-1} day^{-1}) in diets of feedlot-finished lambs on the physicochemical characteristics and fatty acid composition of their meat. Thirty-two uncastrated lambs atan average age of 167 days and an average body weight of 24.76 ± 3.00 kg were distributed into four groups in a completely randomized design with eight animals per group for each treatment. Color values were measured on the longissimus dorsi muscle using a portable colorimeter. To determine the cooking losses, samples of meat were cut and weighed. Individual pieces were cooked in an electric oven to a defined internal temperature (72°C). The composition of fatty acids were measured by gas chromatography.Inclusion of cassava wastewater linearly reduced cooking losses, shear force, and yellow intensity and linearly increased the fat content of the meat. The amounts of myristic, stearic, linoleic, and total fatty acids were changed. Additionally, an effect of cassava wastewater was observed on the amounts of saturated fatty acids, polyunsaturated fatty acids, desirable fatty acids, and n-6:n-3ratio. A positive quadratic effect was observed for the following nutritional quality indices: Δ9 desaturase 16, elongase, at herogenicity, and thrombogenicity. Cassava wastewater changesthe physicochemical characteristics and fatty acid composition of lamb meat. Furtherstudies should be carried outto more accurately determine the fatty acid composition of cassava wastewater to better understand its effectson animal nutrition.

Keywords: by-products, cooking losses, fat, meat color, shear force, nutritional quality.

Efeito da manipueira sobre as características físico-químicas e composição de ácidos graxos da carne de cordeiros terminados em confinamento

RESUMO. Este estudo teve como objetivo avaliar a inclusão de manipueira (0,0; 0,5; 1,0 ou 1,5 L animal^{-1} dia^{-1}) na dieta de cordeiros terminados em confinamento sobre as características físico-químicas e composição de ácidos graxos da carne. Foram utilizados 32 cordeiros não castrados, com idade média de 167 dias e peso médio de 24,76 kg, distribuídos em um delineamento experimental inteiramente casualizado, divididos em quatro grupos com oito animais por grupo para cada tratamento. Os valores de cor foram medidos no músculo longissimus dorsi usando um colorímetro portátil. Para determinar as perdas de cozimento, amostras de carne foram cortadas e pesadas. Os pedaços individuais foram cozidos em um forno elétrico até uma temperatura interna definida (72°C). A composição de ésteres metílicos de ácidos graxos foi medida por cromatografia gasosa. A inclusão de manipueira diminui as perdas por cocção, força de cisalhamento e intensidade de amarelo linearmente, enquanto o teor de gordura da carne aumenta linearmente. A quantidade dos ácidos graxos mirístico, esteárico, linoleico e os ácidos graxos totais foram alteradas. Também foram observados os efeitos da manipueira nas quantidades de ácidos graxos saturados, ácidos gordos poli-insaturados, ácidos graxos desejáveis e proporção de n-6: n-3. Observou-se efeito quadrático positivo para os índices de qualidade nutricional: Δ9 dessaturase 16, elongase, aterogenicidade e trombogenicidade. Em conclusão, a manipueira alterou as características físico-químicas e composição de ácidos graxos da carne de cordeiro. No entanto, outros estudos devem ser realizados para determinar a composição da manipueira de ácidos graxos para elucidar o uso que na alimentação animal.

Palavras-chave: coprodutos, perdas por cocção, gordura, cor da carne, força de cisalhamento, qualidade nutricional.

Introduction

Sheep farming in northeastern Brazil is characterized as a secondary subsistence activity of frequently very low profitability; for this reason, technologies that increase the yields from this activity are demanded. Furthermore, food options must be

broadened to compose diets for the different animal categories, especially foods that provide better animal performance and a higher return to the farmer. The use of alternative foods has emerged as a good energy source to feed ruminants (Cunha, Carvalho, Gonzaga, & Cezar, 2008).

Some by-products from agribusiness such as those generated from cassava flour production (cassava peel, cassava meal, etc) have the potential and availability to beused as energy sources in ruminant nutrition (Pereira et al., 2012). The cassava wastewater, a yellowish liquid resulting from the pressing of cassava to produce the flour and starch,is an example of such energy sources (Curcelli, Bicudo, Abreu, Aguiar, & Brachtvogel, 2008).

On average, the cassava root processing results in approximately 30% of wastewater, which is improperly eliminated, contaminating the soil and groundwater (Almeida, Silva, Lima, Almeida, & Zacharias, 2009). The cassava wastewater disposed in the environment has a high polluting potential due to the amounts of organic material and cyanide compounds, which hare toxic to most aerobic microorganisms (Meneghetti & Domingues, 2008).

As an alternative food, two important considerations about cassava wastewater are note worthy: it may cause serious environmental damage if disposed in the environment and it is a by-product from the cassava root that is rich in sugar and starch, characterizing it as an energy source. Therefore, its use in animal nutrition can reduce the costs involved in the livestock activity while reducing the disposal of this waste in the environment.

Different food sources may change the composition and quality of meat. Studies have shown the effect of including cassava and its by-products on the lipid content and fatty acid composition of lamb meat (Faria et al., 2014; Guimarães et al., 2016). On this basis, cassava wastewater is a potential alternative food for the modulation of meat quality.

However, there is no consensus about the use of cassava wastewater in animal nutrition and meat quality despite the wide use of this by-product as raw material in agriculture. Furthermore, research about cassava wastewater in animal feed in gisscarce. The present study was thus conducted to evaluate the effect of cassava wastewater supplementation on the physicochemical characteristics and fatty acid composition of meat from feedlot-finished lambs.

Material and methods

This study was conducted at Embrapa Tabuleiros Costeiros, located in Frei Paulo, SE, Brazil, and at Universidade Estadual de Maringá (UEM), in Maringá, Parná State, Brazil. Thirty-two uncastrated male Santa Inês lambs (167 days of age and 24.8 ± 3.00 kg bodyweight) were randomly distributed into one of four treatment groups, with eight animals per group differentiated by the inclusion of cassava was tewater. Treatments corresponded to cassava wastewater offered to the animals at the levels of 0.0, 0.5, 1.0, or 1.5 L animal^{-1} day^{-1}.

The basal diet (150 g kg^{-1} crude protein [CP]) was formulated according to Nuclear Regulatory Commission (NRC, 2007), to provide an average daily gain of 0.150 kg per finishing lamb. This diet contained Tifton 85 hay (*Cynodon spp.*) (900 g kg^{-1} dry matter [DM], 108 g kg^{-1} CP, 786 g kg^{-1} neutral detergent fiber [NDF], and 530 *in vitro* dry matter digestibility [IVDMD]), corn screenings (901 g kg^{-1} DM, 55 g kg^{-1} CP, 731 g kg^{-1} NDF, and 461 IVDMD), ground corn, soybean meal, limestone, and a mineral supplement. The roughage feeds (700 g kg^{-1} DM) used were Tifton 85 hay and corn screenings (350 g kg^{-1} DM). The basal diet was off ered as a total mixed ration (Table 1).

Table 1. Ingredients and chemical composition of experimental diets.

	Cassava wastewater (L)				Chemical composition (%)			
Ingredient (%)	0.0	0.5	1.0	1.5	DM	CP	NDF	IVDMD
Tifton 85 hay	35.0	35.0	35.0	35.0	90.0	10.8	78.6	53.0
Corn screenings	35.0	35.0	35.0	35.0	90.1	5.5	73.1	46.1
Soybean meal	18.0	18.0	18.0	18.0	89.09	50.1		80.3
Ground corn	12.0	12.0	12.0	12.0	89.02	8.9		70.8
Cassava wastewater (L)	0.0	0.5	1.0	1.5	43.4			

The liquid residue from the extraction of flour and starch was obtained from the same flour manufactory. The cassava wastewater hadthe following composition: 434 g kg^{-1} DM, 281 g kg^{-1} ash, 66 g kg^{-1} ether extract [EE], 110 g kg^{-1} starch, 16.2 μg HCN mL^{-1} cyanogenic compounds, 6.5 Brix total soluble solids (1 ºBrix is equal to 1 g of sugars per 100 g of solution), acidity of 0.23 (expressed as molar concentration of acids), and pH 4.91.Cassava wastewater does not contain significant amounts of CP, NDF, oracid detergent fiber (ADF).

Before the beginning of the experiment, the animals received anti-parasitic drugs and the effectiveness of control was determined by parasitological examination. Subsequently, they were housed in individual stalls with access to an automatic drinker and an individual feeder.

Lambs were fed daily, at 9 and 16h. The amounts supplied were weighed daily and adjusted according to the animal intake from the previous days, thus ensuring *ad libitum* feeding (1% to 20% orts). The cassava wastewater (0.0, 0.5, 1.0, or 1.5 L) was

supplied in buckets attached to the individual stalls, once daily, in the morning. Before being offered, the cassava wastewater was homogenized to distribute the decanted starch evenly throughout the liquid.

All the cassava waste water used in the trial originated from the same flour manufactory. It was stored in plastic drums (200 L) and left at rest for about 10 days for volatilization of hydrocyanic acid (Pereira et al., 2012).

Samples of basal diet were collected and ground through a 1-mm-sieve screen to evaluate the following components: DM, ash, CP, EE, and IVDMD as described by Silva and Queiroz (2002); NDF and ADF contents as described by Van Soest, Robertson and Lewis (1991); NDF without the use of sodium sulfite and with the inclusion of heat-stable α-amylase (alpha-amylase Termamyl 2x, Tecnoglobo®, Curitiba, Paraná State, Brazil); and organic matter (OM), and total carbohydrates (TC) using equations described by Sniffen, O'connor, Van Soest, Fox and Russell (1992).

Cassava wastewater samples were analyzed to determine DM, ash, and EE as described by Silva and Queiroz (2002). Total cyanide was analyzed by the enzymatic method described by Essers, Bosveld, Grift, Van der Grift and Voragen (1993). The pH, titratable acidity, total soluble solids, and starch were determined according to methods described by Adolfo Lutz Institute (Zenebon, Pascuet, & Tiglea, 2008).

Animals were slaughtered after 70 days in the feedlot at an average body weight of 34.6 and an average age of eight months. After 12 hours of fasting, lambs were transported to a commercial slaughterhouse where they were slaughtered following the usual practices of the Brazilian meat industry after being stunned by an electric shock.

Carcasses were chilled to 4ºC for 24 hin a cold room. Afterwards, they were split lengthwise along the spine and the *longissimus dorsi* (6th to 10th thoracic vertebra) was separated to measure the physical and chemical composition of the meat. The pH was measured after slaughter (initial pH = 6.55) on the hot carcass and after 24 hin the refrigerator at 1ºC (final pH = 5.60) with a pH meter with penetration electrode (HI 996163, Hanna Instruments®, Woonsocket, Rhode Island, USA).

Color values were measured on the *longissimus dorsi* muscle using a portable colorimeter (Chroma Meter CR-410, Konica Minolta®, Osaka, Japan). The samples were allowed to bloom for 30 min. prior to the measurements. The parameters L★, a★, and b★, representing lightness, redness, and yellowness, plusthe chroma (C★) and the hue (h★),were measured in five locations of each sample, and the average was recorded.

To determine the cooking losses, samples of meat were cut and weighed (initial weight). Individual standardized 50-mm-thick pieces were cooked in an electric oven to a defined internal temperature (72°C). When the endpoint temperature was attained, the samples were removed from the electric oven and kept at room conditions until reaching room temperature. The meat was then taken from the plates and weighed. To determine the shear force according to Wheeler, Shackelford and Koohmaraie (2001), the sample was cut from a block of thawed or cooked meat and taken to avoid damage. Sample strips of a least 1-cm thickness were obtained from a 2.5-cm cross-section made parallel to the fiber direction. The sample was sheared at a right angle to the axis. The units of measurement were kg cm^{-2}. The shear force was measured perpendicular to the orientation of muscle fibers with a Warner-Bratzler shear device, adapted to the TA.XT Plus model (Stable Mycro Systems, United Kingdom) and analyzed as the average of six readings of each sample. The samples were completely sheared at a speed of 20 cm s^{-1}.

Laboratory analyses of meat were carried out two months after sampling. The samples were thawed at room temperature (20ºC), ground, homogenized, and analyzed in triplicate. The beef moisture and ash contents were determined according to Association of Official Analytical Chemists (AOAC, 1998). The crude protein content was obtained bythe Kjeldahl method (AOAC, 1998).Total lipids were extracted using a chloroform : methanolsolution (2:1 v/v) (Bligh & Dyer, 1959).

Fatty acid methyl esters were prepared by triacylglycerol methylation according to International Organization for Standardization (ISO, 2000) method no. 5509 with KOH/methanol and n-heptane. Thereafter, the methyl ester composition of fatty acids were measured by gas chromatography (Trace GC Ultra, Thermo Scientific, USA) equipped with an auto sampler, a flame ionization detector at 240ºC, and a fused-silica capillary column (100 m long, 0.25 mm internal diameter, and 0.20 m film thickness, Restek 2560®). Fatty acids were quantified as g 100 g^{-1} lipids and compared with the retention times of methyl ester fatty acids from the tricosanoicacid methyl ester (23:0) sample standard (Sigma-Aldrich®, Brazil). The column parameters were as follows: the initial column temperature of 65ºC was maintained for 8 min., then increased at a rate of 50ºC $min.^{-1}$ to 170ºC; this temperature was maintained for 40 min. and then increased at a rate of 50ºC $min.^{-1}$ to 240ºC and maintained for 28.5 min. The injector and detector temperatures were 220 and 245ºC,

respectively. The gas flow was 1.5 Ml min.$^{-1}$ for hydrogen (carrier gas), 30 mL min.$^{-1}$ for N_2 (auxiliary gas), 35 mL min. $^{-1}$ for H_2, and 350 mL min.$^{-1}$ for compressed air. With amicroliter syringe, 2 Lof the samples were injected with a split ratio of 1:100. Fatty acid peaks were identified by comparison with the retentiontimes of pure methyl ester standards (Sigma-Aldrich®, Brazil).

Based on the fatty acids composition, we calculated the sum of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and desirable and fatty acids (DFA = MUFA + PUFA + C18:0) and defined the PUFA:SFA and n-6:n-3 ratios. The following indices were also calculated: Δ9 desaturase 16 = 100 [(C16: 1cis9)/(C16 + C16 1cis9: 0)]; Δ9 desaturase 18 = 100 [(C18: 1cis9)/(C18: 1cis9 + C18: 0)]; elongase = 100 [(C18: 0 + C18: 1cis9)/(C16: 0 + C16: 1cis9 + C18: 0 + C18: 1cis9)]; atherogenicity = [C12: 0 + 4 (C14: 0) + C16: 0]/(ΣSFA ΣPUFAI +ΣMUFA)]; and thrombogenicity = [(C14: 0 + C16: 0 + C18: 0)/[(0.5 × ΣMUFA) + (0.5 × Σn-6 + (3 × Σn-3) + (Σn-3/Σn-6)], according to Ulbricht and Southgate (1991). These parameters were used to determine the nutritional value of the lipid fraction of the *longissimus dorsi* muscle of Santa Ines lambs.

The data were analyzed by analysis of variance, linear curve estimation, and quadratic regression equations (α= 0.05). Results were analyzed according to a completely randomized design using Statistical Analysis System (SAS, 2002).The criteria used to choose the model were the significance of the regression coefficients (α= 0.05) by the F test (α= 0.05)and the coefficient of determination (R^2,calculated as the ratio between the sum of squares of the regression and the sum of squares of treatments and biological phenomenon).

Results and discussion

The pH value of 5.6 at 24h after slaughter (final pH) was within the normal pH values for lamb meat and did not differ among treatments. Meats with pH values above 6.0 present an anomaly called DFD (dark, firm, dry). However, DFD is rarely observed in lamb meat, and, in this study, the animals were slaughtered in accordance with the animal welfare norms and thus the muscle glycogen reserves secured the right pH decline.

The inclusion of cassava wastewater decreases the cooking losses (%), shear force (kgf), and intensity of yellow while the meat fat content increases linearly (Table 2). Dhanda, Taylor and Murray (2003) pointed out that higher values of cooking losses are related to alow carcass pH, which could lead to PSE (pale, soft, exudative) meat. However, the pH in this study was within the normal range. Thus, the decrease in cooking losses might be related to other factors such as an increase in fat content. According to Lawrie and Rubensam (2005), the water retention capacity is directly related to the fat content; thus, a decrease in cooking losses is expected when the fat content increases.

Table 2. Physical and chemical characteristics of lambs' meat fed with different proportions of cassava wastewater.

	Cassava wastewater (L)				CV	P-value	
	0.0	0.5	1.0	1.5	(%)	L	Q
Cooking losses (%)	16.4	12.2	11.7	11.6	19.7	0.04	0.12
Shear force (kgf)	2.46	2.40	2.20	2.15	17.0	< 0.01	0.09
Moisture (%)	73.8	73.8	73.8	73.8	1.03	0.09	0.07
Crudeprotein (%)	21.6	21.9	22.2	21.9	6.14	0.50	0.65
Lipid (%)	0.77	0.84	0.91	0.99	22.1	0.04	0.74
Ash (%)	3.89	3.64	3.68	3.72	4.87	0.15	0.15
Lightness (L*)	38.4	38.4	37.7	37.8	37.8	0.07	0.26
Redness (a*)	13.5	13.5	13.2	13.2	12.2	0.09	0.40
Yellowness (b*)	8.26	7.90	7.54	7.21	16.2	0.01	0.11
Chroma (C*)	15.7	15.9	14.7	15.0	11.7	0.26	0.12
Tonality (h*)	31.3	31.6	29.8	28.9	13.0	0.22	0.63
Regressionequations						R^2	
Cookinglosses (%)	$\hat{Y} = 15.2 - 2.99x$					0.70	
Shear force (kgf)	$\hat{Y} = 2.47 - 0.23x$					0.93	
Lipid (%)	$\hat{Y} = 0.78 + 0.14x$					0.71	
Yellowness (b*)	$\hat{Y} = 8.25 - 0.70x$					0.99	

CV: coefficient of variation. L: linear equation. Q: quadratic equation.

The shear force, which is related to the muscular fiber resistance, decreased linearly with the increase in cassava wastewater inclusion. This might be related to the lower cooking losses observed. According to Aaslyng, Bejerholm, Ertbjerg, Bertram and Andersen (2003), a reduction of cooking losses implies juicier and tenderer meat because more water is within the fiber. However, for all treatments, the meat should be considered tender, because, according to Costa et al. (2009), meat is classified as tender when its shear force is ≤ 8 kgf cm^{-2}; acceptable when shear force is between 8 and 11 kgf cm^{-2}; and tough when shear force is > 11 kgf cm^{-2}. Cassava wastewater inclusion increased the fat content of the meat, which is important, since the amount of fat is one of the major concerns related to slaughter age (Santos-Silva, Mendes, & Bessa, 2002).

The decrease in yellow intensity might be related to the amount and type of pigments of the fat in the carcass. Rodrigues and Andrade (2004) who compared meat from cattle and buffaloes and observed that the latter had a lower yellow intensity due to the lower amount of fat and carotenoid pigment contents in their meat. In addition, according to Dhanda et al. (2003) and Majdoub-Mathlouthi, Saïd, Say and Kraiem (2013), fat

pigments can be influenced by the diet. High contents of carotenoids, the major pigments present in animal diets, especially in green forages, can be incorporated in fat tissues, increasing the yellowness of fat. The low amount of pigments in cassava waste water may be related to a lower ingestion of such pigments, resulting in whiter fat and decreasing the yellow intensity.

Recent research has demonstrated a diversity of results off atty acid composition in the meat; e.g., Juárez et al. (2008) concluded that the production system, associated with the breed and the diet, was the main factor explaining variations in the meat fatty acid profile. In fact, in this study, the inclusion of cassava wastewater changed the fatty acid composition of lamb meat. The amounts of myristic (14:0) (16:1n-7), stearic (18:0), and linoleic (18:2n6c) fatty acids; 20:4n-6; and total fatty acids were changed(Table 3).Among the ten fatty acids identified in the composition of lamb meat, those with highest representation were oleic (18:1n9c), palmitic (16:0), and stearic (18: 0), respectively (Table 3), similar to the reports of Barros et al. (2015).

An influence of cassava wastewater was also observed on the amounts of saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA), and desirable fatty acids (DFA) (Table 3). The quantities off at ty acids were studied to assess and identify the risk factor of thefood to increase the human blood cholesterol level.

The concentration of desirable fatty acids is expressed by the sum of the PUFA and stearic acid. Despite being saturated, stearic acid is considered a neutral fatty acid (Prado, 2004) because it can be converted to oleic acid in the human body, and oleic acid is known to be a reducer of cholesterol and low-density lipoproteins. Thus, cassava wastewater has the ability to increase the stearic acid content, consequently improving the nutritional quality of lamb meat.

A quadratic effect of cassava wastewater was also observed on n-6:n-3 ratio and on the nutritional indices Δ9 desaturase 16, elongase, and atherogenicity, while thrombogenicity showed a linear effect (Table 3).

Table 3. Fatty acid composition of meat from lambs fed different proportions of cassava wastewater.

Fatty acids (g 100 g^{-1})	Cassava wastewater(L)				CV	P-value	
	0.00	0.50	1.00	1.50	(%)	L	Q
10:0 (capric)	0.09	0.09	0.09	0.10	7.62	0.22	0.12
12:0 (lauric)	0.09	0.06	0.07	0.28	34.8	0.09	0.12
14:0 (myristic)	2.16	1.78	1.77	2.04	14.0	0.54	0.03
16:0 (palmitic)	21.4	21.0	21.7	21.6	2.64	0.32	0.40
16:1n-7	1.82	1.46	1.55	2.13	18.7	0.18	0.01
18:0(stearic)	17.3	23.2	21.8	23.8	9.59	> 0.01	0.40
18:1n9c(oleic)	31.7	30.4	35.7	29.7	9.75	0.50	0.11
18:2n6c(linoleic)	4.61	6.06	4.62	4.86	7.52	0.45	0.01
18:3n3(α-linolenic)	0.78	0.67	0.47	0.63	23.8	0.08	0.10
20:4n-6	2.02	2.77	2.84	2.38	22.3	0.37	0.04
Total fattyacids	80.6	85.2	86.1	86.7	2.12	< 0.01	0.01
Conjugatedlinoleicacid	0.66	0.46	0.37	0.45	31.7	0.06	0.08
n-6:n-3	5.92	9.11	7.67	7.83	15.8	0.94	0.02
Saturated fatty acids (SFA)	41.0	46.2	43.3	47.8	5.68	0.01	0.78
Monounsaturated fatty acids	33.6	31.8	37.3	31.8	8.43	0.09	0.21
Polyunsaturated fatty acids (PUFA)	7.41	9.50	7.94	7.88	10.2	0.94	0.02
PUFA:SFA	0.18	0.20	0.18	0.17	12.5	0.21	0.08
Desirable fatty acids	58.3	64.5	64.9	63.5	2.98	< 0.01	< 0.01
Nutritional quality index							
Δ9 desaturase 16	7.83	6.50	6.67	8.89	14.7	0.20	0.01
Δ9 desaturase 18	64.7	56.7	64.4	55.2	7.08	0.06	0.78
Elongase	67.9	70.4	70.4	69.3	1.96	0.20	0.02
Atherogenicity	0.62	0.51	0.56	0.53	2.46	< 0.01	< 0.01
Thrombogenicity	1.61	1.63	1.66	1.69	2.08	0.01	0.26
Regression equations							
14:0.Myristic)	$\hat{Y} = 2.16 - 1.05x + 0.65x^2$					$r^2 = 0.99$	
16:1n-7	$\hat{Y} = 1.92 - 1.19x + 0.93x^2$					$r^2 = 0.99$	
18:0 (Stearic)	$\hat{Y} = 18.6 + 3.22x$					$r^2 = 0.46$	
18:2n6c (Linoleic)	$\hat{Y} = 4.84 + 1.68x - 1.21x^2$					$r^2 = 0.27$	
20:4n-6	$\hat{Y} = 2.02 + 2.05x - 1.22x^2$					$r^2 = 0.99$	
Total fattyacids	$\hat{Y} = 82.0 + 3.15x$					$r^2 = 0.64$	
n-6:n-3	$\hat{Y} = 6.23 + 5.40x - 3.03x^2$					$r^2 = 0.62$	
Saturated fatty acids	$\hat{Y} = 41.9 + 3.52x$					$r^2 = 0.56$	
Polyunsaturated fatty acids	$\hat{Y} = 7.67 + 3.20x - 2.15x^2$					$r^2 = 0.46$	
Desirable fatty acids	$\hat{Y} = 58.5 + 14.7x - 7.68x^2$					$r^2 = 0.97$	
Δ9desaturase 16	$\hat{Y} = 7.86 - 4.67x + 3.56x^2$					$r^2 = 0.99$	
Elongase	$\hat{Y} = 68.0 + 6.31x - 3.65x^2$					$r^2 = 0.97$	
Atherogenicity	$\hat{Y} = 0.61 - 0.17x + 0.09x^2$					$r^2 = 0.54$	
Thrombogenicity	$\hat{Y} = 1.61 + 0.05x$					$r^2 = 0.68$	

CV: coefficient of variation; L: linear equation; Q: quadratic equation.

According to Garcia et al. (2008), the n-6:n-3 ratio can be influenced by the diets. For animals finished in the feedlot, the ratio ranges from 6.0 to 10 because the grains are rich in 18:2n-6 (Boufaïed et al., 2003). These results were confirmed by this study, in which the n-6:n-3 ratio was influenced by the inclusion of cassava wastewater (quadratic effect), with values ranging from 5.92 to 9.11.

Lower atherogenicity and thrombogenicity indices lead to a greater potential to prevent coronary heart diseases. Cassava wastewater changed the atherogenicity index (quadratic effect). Thus, this effect should be betterstudied to elucidatethe capacity of cassava wastewater to improve the fatty acid profile of lamb meat. However, Arruda et al. (2012) reported no effect of diets on nutritional quality indices of lamb meat, showing mean atherogenicity and thrombogenicity indices of 0.60 to 0.67 and 1.31 to 1.46, respectively.

The results observed in this study show that cassava wastewater has sufficient amounts of fatty acids to change the fatty acid composition of meat. However, new studies should be conducted to determine the fatty acid composition of this product. Moreover, the chemical composition of cassava wastewater has not yet been defined and neither has it been determined whether this by-product can be included in animal feed, considering its broad use as raw material in agriculture and the fact that research on animal feed is still in early stages.

Conclusion

Cassava wastewater changes the physical and chemical characteristics of lamb meat, increasing the lipid contents, reducing cooking losses and shear force, and changing the fatty acid composition and nutritional quality indices. Further studies should be carried out to determine the fatty acid composition of cassava wastewater to elucidate its use in animal nutrition.

References

Aaslyng, M. D., Bejerholm, C., Ertbjerg, P., Bertram, H. C., & Andersen, H. J. (2003). Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. *Food quality and preference, 14*(4), 277-288.

Almeida, S. R. M., Silva, A. M., Lima, J. P., Almeida, A. M. M., & Zacharias, F. (2009). Avaliação do potencial nutritivo da Manipueira na dieta de ovinos deslanados. *Cadernos de Agroecologia, 4*(1), 1434-1438.

Arruda, P. C. L., Pereira, E. S., Pimentel, P. G., Bomfim, M. A. D., Mizubuti, I. Y., Ribeiro, A. E. L., ... Regadas Filho, J. G. L. (2012). Perfil de ácidos graxos no Longissimus dorsi de cordeiros Santa Inês alimentados com diferentes níveis energéticos. *Semina: Ciências Agrárias, 33*(3), 1229-1240.

Association of Official Analytical Chemists [AOAC]. (1998). *Official methods of analysis* (16th ed.). Gaithersburg, MD: AOAC.

Barros, M. C. C., Silva, F. F., Silva, R. R., Simionato, J. I., Guimarães, G. S., Silva, L. L., & Facuri, L. M. A. M. (2015). Glicerina bruta na dieta de ovinos confinados: Composição centesimal e perfil de ácidos graxos do longissimus dorsi. *Semina: Ciências Agrárias, 36*(1), 431-442.

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian journal of biochemistry and physiology, 37*(8), 911-917.

Boufaïed, H., Chouinard, P., Tremblay, G., Petit, H., Michaud, R., & Bélanger, G. (2003). Fatty acids in forages. I. Factors affecting concentrations. *Canadian Journal of Animal Science, 83*(3), 501-511.

Costa, R. G., Batista, A. S. M., Azevedo, P. S., Queiroga, R. C. R., Madruga, M. S., & Araújo Filho, J. T. (2009). Lipid profile of lamb meat from different genotypes submitted to diets with different energy levels. *Revista Brasileira de Zootecnia, 38*(3), 532-538.

Cunha, M. G. G., Carvalho, F. F. R., Gonzaga Neto, S., & Cezar, M. F. (2008). Características quantitativas de carcaça de ovinos Santa Inês confinados alimentados com rações contendo diferentes níveis de caroço de algodão integral. *Revista Brasileira de Zootecnia, 37*(6), 1112-1120.

Curcelli, F., Bicudo, S. J., Abreu, M. L., Aguiar, E. B., & Brachtvogel, E. L. (2008). Uso da mandioca como fonte na dieta de ruminantes domésticos. *Revista Raízes e Amidos Tropicais, 4*(1), 65-77.

Dhanda, J. S., Taylor, D. G., & Murray, P. J. (2003). Part 1. Growth. carcass and meat quality parameters of male goats: effects of genotype and liveweight at slaughter. *Small Ruminant Research, 50*(1), 57-66.

Essers, S. A. J. A., Bosveld, M., Van der Grift, R. M., & Voragen, A. G. J. (1993). Studies on the quantification of specific cyanogens in cassava products and introduction of a new chromogen. *Journal of the Science of Food and Agriculture, 63*(3), 287-296.

Faria, P. B., Pinto, A. M. G., Costa, S. F., Teixeira, J. T., Romitti, F. D., Carvalho, P., & Silva, J. N. (2014). Efeito da casca de mandioca sobre a qualidade da carne e parâmetros ruminais de ovinos. *Archivos de Zootecnia, 63*(243), 437-448.

Garcia, P. T., Pensel, N. A., Sancho, A. M., Latimori, N. J., Kloster, A. M., Amigone, M. A., & Casal, J. J. (2008). Beef lipids in relation to animal breed and nutrition in Argentina. *Meat science, 79*(3), 500-508.

Guimarães, G. S., Silva, F. F., Silva, L. L., Silva, R. R., Simionato, J. I., & Damásio, J. M. A. (2016). Centesimal and fatty acid composition of the longissimus muscle of confined lambs fed diets containing cassava peels. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia, 68*(5), 1325-1333.

International Organization for Standardization [ISO]. (2000) *Animal and vegetable fats and oils. Analysis by gas chromatography of methyl esters of fatty acids*. Geneva, CH: IOS.

Juárez, M., Horcada, A., Alcalde, M. J., Valera, M., Mullen, A. M., & Molina, A. (2008). Estimation of factors influencing fatty acid profiles in light lambs. *Meat Science, 79*(2), 203-210.

Lawrie, R. A., & Rubensam, J. M. (2005). *Ciência da carne* (Vol. 6). Porto Alegre: Artmed.

Majdoub-Mathlouthi, L., Saïd, B., Say, A., & Kraiem, K. (2013). Effect of concentrate level and slaughter body weight on growth performances. carcass traits and meat quality of Barbarine lambs fed oat hay based diet. *Meat Science, 93*(3), 557-563.

Meneghetti, C. C., & Domingues, J. L. (2008). Características nutricionais e uso de subprodutos da agroindústria na alimentação de bovinos. *Revista Eletrônica Nutritime, 5*(2), 512-536.

Nuclear Regulatory Commission [NRC]. (2007). *Nutrient requirements of small ruminants*. Washington, DC: National Academies Press.

Pereira, V. L. A., Oliveira, J. C. V., Santos, D. C., Santos Filho, A. S., Silva, M. C., Silva, V. M., ... Silva, L. R. (2012). Adição do subproduto da mandioca (manipueirana) na dieta de vacas Girolando em lactação. *Paper presented at the VII Congresso Nordestino de Produção Animal*, Maceió, AL, Brasil.

Prado, I. N. (2004). *Conceitos sobre a produção com qualidade de carne e leite*. Maringá, PR: Eduem.

Rodrigues, V. C., & Andrade, I. F. (2004). Chemical physical meat characteristics of buffaloes and cattle entire and castrated. *Revista Brasileira de Zootecnia, 33*(6), 1839-1849.

Santos-Silva, J., Mendes, I. A., & Bessa, R. J. B. (2002). The effect of genotype. feeding system and slaughter weight on the quality of light lambs: 1. Growth. carcass composition and meat quality. *Livestock Production Science, 76*(1), 17-25.

Silva, D. J., & Queiroz, A. C. (2002). *Análise de alimentos: métodos químicos e biológicos* (3a ed.). Viçosa, MG: UFV.

Sniffen, C. J., O'connor, J. D., Van Soest, P. J., Fox, D. G., & Russell, J. B. (1992). A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *Journal of Animal Science, 70*(11), 3562-3577.

Statistical Analysis System [SAS]. (2002). *STAT user's guide: statistics*. *Version 9.1.* Cary, NC: Statistical Analysis System Institute Inc.

Ulbricht, T. L. V., & Southgate, D. A. T. (1991). Coronary heart disease: seven dietary factors. *The Lancet, 338*(8773), 985-992.

Van Soest, P. J., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber. neutral detergent fiber. and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*(10), 3583-3597.

Wheeler, T. L., Shackelford, S. D., & Koohmaraie, M. (2001). Shear force procedures for meat tenderness measurement. *Roman L. Hruska U. S. Meat Animal Research Center*. Clay Center, NE: USDA.

Zenebon, O., Pascuet, N. S., & Tiglea, P. (2008). *Normas analíticas do Instituto Adolfo Lutz: métodos químicos e físicos para a análise de alimentos* (4a ed.). São Paulo, SP: Instituto Adolfo Lutz.

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