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Meat Characteristics of Nellore Cattle Fed Different Levels of Lipid-Based Diets

Erico da Silva Lima[1], Jozivaldo Prudêncio Gomes de Morais[2], Roberto de Oliveira Roça[3], Quézia Pereira Borges da Costa[4], Ernani Nery de Andrade[5], Vanessa Pereira Vaz[6], Tiago Neves Pereira Valente[7] & Dorival Pereira Borges da Costa[8]

[1] Programa de Mestrado em Saúde Ambiental, FMU, São Paulo, SP, Brazil

[2] Centro de Ciências Agrárias, UFSCar, Araras, SP, Brazil

[3] UNESP/FCA, Botucatu, SP, Brazil

[4] Instituto Federal do Mato Grosso, Campo Novo do Parecis Campus, MT, Brazil

[5] Faculdade de Ensino Superior e Formação Integral, FAEF, Garça, SP, Brazil

[6] UNESP/FMVZ, Botucatu, SP, Brazil

[7] Instituto Federal Goiano, Posse Campus, GO, Brazil

[8] Instituto Federal do Mato Grosso, Cuiabá Campus, Bela Vista, MT, Brazil

Correspondence: Erico da Silva Lima, Campus Ponte Estaiada (HOVET), Rua Ministro Nelson Hungria, 541, Real Parque, Morumbi, São Paulo, SP, Brazil. Tel: 55-11-3758-3009. E-mail: ericozoo1@yahoo.com.br

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Abstract

The objective of this study was to determine the effect of the dietary inclusion of lipid-based diets (whole cottonseed and protected fat) on the centesimal composition, fatty acid profile, and sensory properties of meat from finishing Nellore cattle. The study was carried out from August to October 2009. Thirty nine uncastrated Nellore males with average initial body weight of 494.1 ± 10.1 kg and 36 months of age were housed for 63 days in pens with thirteen animals each. A completely randomized design with three treatments and thirteen replications was used. The treatments evaluated were: feed with 2.50% cottonseed (control diet); feed with 11.50 % cottonseed; and feed with 3.13% cottonseed added of protected lipid (PL), all on a dry matter basis. No differences between treatments were observed for moisture, protein, and ash contents. However, the addition of protected fat caused an increase in the percentage of ether extract in the meat. Diets containing cottonseed or protected lipid did not affect fatty acid concentration in the meat. The intensity of the aroma, strange aroma, flavor, strange flavor, juiciness, color, and overall appearance were similar between treatments, except for tenderness, which was positively affected in cattle fed a diet in which the only lipid source was cottonseed. The study demonstrated that the addition of PL in the diets of finishing cattle led to greater levels of intramuscular fat, but to less tender meat than the other treatments.

Keywords: beef quality, centesimal composition, fatty acid profile, protected fat, sensory evaluation, whole cottonseed

1. Introduction

Cattle meat is one of the most important foods in an adequate human diet. However, this food has been recently associated with high cholesterol levels, which is a risk factor for cardiovascular diseases (Scollan et al., 2006). This fact is directly related with the characteristics of the fat in cattle meat, which has greater concentration of saturated fatty acids and lower ratio between polyunsaturated and saturated fatty acids, as unsaturated fatty acids from the diet are hydrogenated in the rumen, different from what happens to ingested fat in monogastric animals (French et al., 2000).

Nowadays, given the demands of the consumers for high quality meat caused by changes in economic stability, increased purchasing power and concerns about health, the use of agroindustrial by-products in the feed animals should be analyzed for better understanding of their impacts on cattle meat quality.

Consumer interest in the beneficial effects of some foods has been growing. These consumers may be searching for foods that provide additional physiological benefits, besides satisfying basic nutritional needs (Hasler, 1998). This observation has stimulated animal production studies on solutions to decrease the level of unsaturated fatty acids and increase polyunsaturated ones in foods of animal origin. It is possible to change the content of different fatty acids in the muscles of animals by altering their diets, leading to the production of healthier meats (Andrade et al., 2001).

Nutritional manipulation of the rumen environment is one strategy used to change the lipid profile and composition of ruminant meats (Demeyer & Doreau, 1999). Therefore, it is important to study the effect of animal diets or feed ingredients on human health, as well as on the nutritional and sensory quality of the meats and their preservation characteristics.

Whole cottonseed (CS) and calcium salts of fatty acids (CSFA) are options in cattle diets, once there are reports in the literature that a fraction of the fat in these ingredients goes through the rumen without being attacked by the microorganisms, is later on degraded and absorbed in the small intestines, producing meat of better quality (Huerta-Leidenz et al., 1991; Jenkins, 1993; Van Soest, 1994; Costa et al., 2013). Based on these facts, the objective of this study was to evaluate the centesimal composition, the fatty acid profile, and the sensory characteristics of *M. longissimus thoracis* of Nellore cattle fed diets containing lipid sources.

2. Materials and Methods

2.1 Study Location

The study was carried out in the Chapéu de Couro Farm, located in the city of Aguaí/SP, Brazil, at 22°04′00″ South, 47°09′03″ West, average altitude of 615 m above sea level. The region is characterized by a hot and humid seasons from October to March, followed by a cold and dry season from May to September. The climate of the region is Cwa in the Köppen classification (mesothermal, with hot and humid summers and dry winters).

2.2 Animal Management and Treatment

A group of 39 uncastrated, Nellore animals raised in *Brachiaria humidicola* pastures was used in the study. Mean age of the animals was 36 months and initial mean live weight was 494.1 ± 10.1. Animals were identified and dewormed with Ivermectin 1% before the beginning of the trial.

Then, animals were randomly assigned to one of three treatments, based on dry matter: feed with 2.50% CS (control diet), feed with 11.50% CS, and feed with 3.13%% CS added of 1.77% protected lipid (PL).

Animals were confined for 63 days (experimental period) in collective pens of 247 m^2 (19 m^2 per animal). The confinement facility was made up of three pens with sand floors, with 13 animals per pen. Feeders and drinkers in these pens were provided with roofs and animals had free access to them. Feeders were made of concrete, and the length available per animal was 0.70 m. A 10-day period was used for the adaptation to the diet and management prior experimental period, in which concentrate was gradually added to the feed, until a 50:50 forage:concentrate ratio was reached.

The experimental diets were formulated in the CNCPS software 4.0 (CNCPS, 2000) for uncastrated finishing cattle to provide weight gains of 1.4 kg/animal/day. Forage:concentrate ratio was 50:50 on a dry matter basis. All the concentrate ingredients and forage were weighted in order to prepare the experimental diets, using electronic weighing scale kg. Sugar cane chopped was used as forage, and concentrate was made up of urea, cracked corn kernels, citrus pulp, cotton meal, CS and/or PL. The PL used in this study was made from soybean vegetable oil and had fatty acid calcium salts in its composition. Animals were fed twice a day at 8 am and 4 pm, in a total mix diet, with about 5% leftovers that were weighted in the morning for diet adjustment. Nutritional composition of the diets is shown in Table 1.

Table 1. Chemical composition of the experimental diets on a dry matter basis

Ingredients (%)	Dietary treatments		
	2.50% CS (control)	11.50% CS	3.13% CS + PL
Sugar cane	50.00	50.00	50.00
Cracked corn	14.64	13.07	13.12
Citrus pulp	21.61	17.81	20.61
Cottonseed	2.50	11.50	3.13
Cottonseed meal	9.30	5.78	9.42
Urea	0.83	0.83	0.83
Protected fat	-	-	1.77
Mineral mix [1]	0.83	0.83	0.83
Potassium chloride	0.28	0.17	0.28
Ionophores	0.01	0.01	0.01

Note. [1]Composition /kg: P = 60 g; Ca = 180g; Mg = 5 g; S = 17g; Na = 135 g; Cu = 650 mg; Mn = 500 mg; Zn = 2400 mg; I = 48 mg; Co = 38 mg; Se= 12 mg; CS = cottonseed; PL = protected lipid.

2.3 Procedures for Data Collection

After thawing, composite samples of a 21-day period were obtained. Samples of feed and forage were weighted and pre-dried at 60 °C for 72 hours. Then, they were weighted again in a mill with 1-mm sieves, and stored in plastic bags. Samples of the experimental diets were sugar cane and concentrate which were collected every seven days, placed in plastic bags and stored in at -4 ^{o}C for subsequent measurements.

The samples were analyzed for Proximate Analysis according to AOAC (1990) and NDFom and ADFom (excluding ash) according to procedures of Van Soest et al., 1991), and lignin by the sulphuric acid method (Lignin (sa), after a sequential neutral-acid detergent extraction (Van Soest et al., 1991). In the NDF analyses, thermostable α-amylase was used without sodium sulfite (Mertens, 2002). Non-fiber carbohydrates (NFC) in the ingredients of the diets were determined by the following equation, according to Sniffen et al. (1992), NFC = 100 – (%NDFcp + %CP + %EE + %MM). Due to the presence of urea in the diets, NFC in them were calculated as indicated by Hall (2000): NFC = 100 – [(%CP – %CP from urea + %urea) + %NDFcp + %EE + %Ash]. Estimated metabolizable energy (ME) in Mcal/kg of DM was determined according to the NRC (1996) recommendations, considering that 1 kg of total digestible nutrients (TDN) contains 4.409 Mcal of digestible energy (DE), using 0.82 as the conversion factor to transform DE in ME. Analyses of the feed samples were carried out in the Food Analysis Laboratory at the Animal Nutrition and Improvement Department of Faculdade de Medicina Veterinária e Zootecnia at Universidade Estadual Paulista, Botucatu campus. Results of these analyses are shown in Tables 2 and 3.

Table 2. Mean chemical composition of ingredients used in the experimental diets as percentage dry matter

Ingredients	DM (%)	% dry matter						
		CP	EE	NFC	NDFmo	ADFmo	LIG	MM
Sugar cane	30.27	2.82	2.93	29.06	62.43	39.56	6.85	2.76
Cracked corn	87.02	8.73	4.46	71.46	14.42	5.32	2.75	0.93
Citrus pulp	87.94	5.87	3.5	64.78	21.38	16.75	7.52	4.47
Cottonseed	91	19.67	20.83	1.36	54.65	45.44	17.03	3.49
Cottonseed meal	87.24	46.08	1.94	0.12	45.66	28.32	9.91	6.2
Protected lipid	95.47	-	85.21	-	-	-	-	14.79
Urea	99.51	287.84	-	-	-	-	-	-

Note. NFC according to Sniffen et al. (1992).

Table 3. Mean chemical composition of experimental diets used in different levels of cotton seed

Items	Diets		
	2.50% CS (control)	11.50% CS	3.13% CS + PL
DM (%)	58.09	58.50	58.26
CP (% dry matter)	11.11	10.90	11.11
EE (% dry matter)	3.57	5.18	5.11
NFC (% dry matter)	38.61	35.03	36.88
NDFmo (% dry matter)	43.56	45.83	43.52
MM (% dry matter)	3.15	3.06	3.38
TDN[1]	67.55	68.16	68.99
ME[2]	2.44	2.46	2.49

Note. [1] Estimated in the feed composition according to the CQBAL 3.0 (2012) and the NRC (2001); [2] ME = estimated metabolizable energy, in Mcal/kg of DM, according to the NRC (1996).

2.4 Slaughter Procedures and Sample Preparations

After 63 days of the study, animals were weighted for the last time after a 14-h solid food fasting. Mean final live weight was 577.01 kg ± 11.34. Soon after being weighted, animals were taken to a slaughterhouse (FRIGONOBRE, in the city of Torrinha, state of São Paulo), 166 km from the study site, in solid food fasting until the moment they were slaughtered. Animals were slaughtered according to the regular flow of the industry. After slaughter, carcasses were identified and divided into two halves that were kept in a cold chamber for 24 hours at 2 °C. Then, part of the *M. longissimus thoracis* of each animal was removed between the 12th and 13th rib of the left half carcass, and divided in three samples (steaks). Steaks were 2.5 cm thick and were identified and stored individually in plastic bags under vacuum. One of the samples was used for the determination of the centesimal composition, another for fatty acid profile, and the third one was used in sensory analysis.

Then, samples were frozen in a freezer at -18 °C at Universidade Estadual Paulista, Faculdade de Ciências Agronômicas, Botucatu campus, at the Animal Products Technology Laboratory. Before the centesimal composition and fatty acid profile were analyzed, samples of *M. longissimus thoracis* were thawed in refrigerator for 24 hours and then removed from the plastic bags.

2.5 Chemical Analysis of the Meat

For the centesimal composition of *M. longissimus thoracis* of each animal, moisture content was determined according to the AOAC 39.1.02 (2007). Total nitrogen was based on micro Kjeldahl (AOAC 39.1.19, 2007). Protein was determined as a function of total nitrogen multiplied by 6.25. Ether extract was determined according to AOAC 39.1.05 (2007). Fixed mineral residue was determined by the AOAC 39.1.09 (2007).

2.6 Chromatographic Analysis of Fatty Acid Composition

Samples of *M. longissimus thoracis* of each animal were used to determine the fatty acid profile. The analysis of methyl esters of fatty acids was carried out in a gas chromatograph (Shimadzu, model GC-17A) equipped with an ionization flame detector, split/splitless injector, and fused silica capillary column with polyethylene glycol as the stationary phase (DB-Wax, 60 m × 0.25 mm, J&W Scientific). The following chromatographic conditions were used: injector temperature, 230 °C; initial column temperature of 80 °C for 2 minutes at 3 °C per minute rate, followed by a raise to 180 °C at 30 °C/min rate; this temperature was maintained for 30 minutes, followed by another raise to 200 °C at 3 °C/minute rate; this temperature was maintained for 108 minutes. Detector temperature was 240 °C, with helium as the dragging gas at a total flow of 8.0 mL/min; sample division ratio was 1:50. Retention times of the methyl ester standards (Sigma-Aldrich) were compared for the identification of the fatty acids, whereas quantification was carried out by the normalization of the area, and results were expressed in percentage area of each fatty acid over total fatty acid area (%) (Hartman & Lago, 1973). Desirable fatty acids were determined by the sum of unsaturated fatty acids and C18:0, and undesirable fatty acids were calculated by the sum of C14:0 and C16:0 according to Huerta-Leidenz et al. (1991).

2.7 Sensory Analysis

Sensory analysis of *M. longissimus thoracis* of each animal was carried out after samples were thawed in

refrigerator (+/-20 hours at 2.5 ± 0.5 °C) and heated on automatic superposed grills. After an internal temperature of 71 °C was reached in the geometric center of the sample, the steak was removed from the grill. Samples were cut in cubes of similar size and, later on, heated on a microwave oven for 30 seconds until temperature reached 50 °C. They were immediately and randomly distributed to the panelists in sterile Petri dishes codified with four-digit numbers, together with a glass of water. Sensory evaluations were conducted according to Meilgaard et al. (1990), using 11 trained panelists. The following sensory tests were used, in the following order, with a 9-point scale: aroma intensity (ranging from absent to extremely intense), strange aroma (ranging from absent, 1 to extremely strong, 9), flavor (ranging from extremely bad to extremely good), strange flavor (ranging from absent, 1 to extremely intense,9), tenderness (ranging from extremely tender, 1 to extremely hard, 9), juiciness (ranging from extremely dry, 1 to extremely juicy, 9), color (ranging from bright cherry red to dark red) and overall appearance (ranging from very bad to very good).

2.8 Statistical Procedures and Model Evaluation

A completely random design experiment with 3 treatments and 13 repetitions was used, according to the Yij = μ + Ti + eij model, where: Yij is the value observed in the j^{th} experimental unit (animal) that received the i^{th} treatment; μ is the overall mean; Ti is the fixed effect of the i^{th} treatment; while eij is the experimental error related to the experimental unit. The variables centesimal composition and FA profile were analyzed by means of the GLM (Generalized Linear Models) of the SAS (2002) software, and means were compared using Tukey test at a 5% significance level. Statistical analysis of the sensory panel was based on the random block design with three treatments and eleven repetitions (panelists).

3. Results

No difference was observed on the moisture, protein and ash contents of *M. longissimus thoracis* ($P > 0.05$) between the treatments that included PL or increased CS levels in the diet (Table 4).

Table 4. Means, standard errors (SE) and probability (P-value) of the centesimal composition of the meat for the different treatments

Characteristics	Diets			Mean	SE	P-value
	2.50% CS (control)	11.50% CS	3.13% CS + PL			
Moisture (%)	73.91	73.27	73.25	73.48	0.22	0.08
Protein (%)	23.46	24.35	23.86	23.89	0.29	0.11
Ether extract (%)	0.94^{b}	0.96^{b}	1.41^{a}	1.10	0.13	0.03
Ashes (%)	1.18	1.23	1.15	1.19	0.02	0.06

Note. ^{ab}Means followed by different letters script in the same rows are significantly different ($P < 0.05$); CS = cottonseed; PL = protected lipid; SE = standard error.

The addition of PL in the diet three increased ($P < 0.05$) percent intramuscular fat (%EE of the muscle) in relation to the other feeds (Table 4).

The proportion of fatty acids in PL as a feed ingredient in the present study were: 53.53% saturated fatty acids (SFA), 42.59% monounsaturated fatty acids (MUFA) and 2.96% polyunsaturated fatty acids (PUFA), with some fatty acids of importance such as oleic acid (34.52%), γ-linolenic acid (0.94%) and α-linolenic acid (1.04%). Bertrand et al. (2005) determined the following proportion of fatty acids for CS: 27.83% SFA, 16.02% MUFA and 55.9% PUFA, with some fatty acids of importance such as oleic acid (15.45%), and linolenic acid (55.72%).

Although PL treatment showed greater EE content (Table 4), which indicates greater percent intramuscular fat, there were no differences ($P > 0.05$) between the diets in the present study, in terms of the FA profile in the meat (Table 5). It was also noted that oleic acid (C18:1n9c), was found in the greatest proportion, whose mean content was 37.32%, followed by palmitic acid (C16:0), with 28.90%, and stearic acid (C18:0), with 21.53% (Table 5).

Table 5. Means, standard errors (SE) and probabilities (P-value) of the fatty acid profile (in% total fatty acid relative area) of the meat for the different treatments

Fatty acid profile	Diets			Mean	SE	P-value[1]
	2.50% CS (control)	11.50% CS	3.13% CS + PL			
C8:0 - (Caprylic)	0.03	0.03	0.00	0.02	0.02	0.45
C11:0 - (Undecanoic)	0.29	0.46	0.25	0.34	0.09	0.31
C12:0 - (Lauric)	0.11	0.14	0.07	0.11	0.04	0.46
C14:0 - (Myristic)	5.09	5.24	4.91	5.08	0.41	0.85
C15:0 - (Pentadecanoic)	0.46	0.49	0.45	0.47	0.10	0.96
C15:1 - (Pentadecenoic)	0.32	0.25	0.31	0.29	0.06	0.65
C16:0 - (Palmitic)	28.40	29.47	28.81	28.90	0.90	0.70
C16:1 - (Palmitoleic)	4.65	3.33	4.80	4.26	0.71	0.29
C17:0 - (Margaric)	1.51	1.21	1.48	1.40	0.33	0.78
C17:1 - (Heptadecenoic)	0.09	0.00	0.12	0.07	0.05	0.25
C18:0 - (Stearic)	22.73	20.70	21.17	21.53	1.93	0.74
C18:1n9c - (Oleic)	35.87	37.76	38.33	37.32	1.70	0.57
C18:1n9t - (Elaidic)	0.57	0.49	0.43	0.50	0.10	0.63
C20:0 - (Araquidic)	0.48	0.36	0.23	0.35	0.13	0.41
C20:2 - (Eicosadienoic)	0.35	0.42	0.36	0.38	0.08	0.80
C20:3n3 - (Eicosatrienoic)	0.05	0.02	0.01	0.03	0.02	0.48
C20:5n3 - (Eicosapentaenoic)	0.07	0.04	0.00	0.04	0.03	0.34
C22:1n9 - (Erucic)	0.92	0.80	0.95	0.89	0.20	0.36
C22:2 - (Docosadienoic)	0.08	0.03	0.02	0.04	0.03	0.40
Non-identifiable	2.13	2.07	2.53	2.24	0.43	0.72

Note. [1]According to Tukey test ($P < 0.05$); t - trans; c – cis; n = position of the double bonds; CS = cottonseed; PL = protected lipid.

There were no differences ($P > 0.05$) between the diets for the proportion of SFA, MUFA and PUFA in the meat of the animals in this study, according to the lipid sources used (Table 6). The inclusion of protected fat or CS in the diet did not change the proportion of desirable fatty acids (FADes) and undesirable fatty acids (FAUnd) in the meat (Table 6).

Table 6. Means for fatty acid profiles of the meat from the different treatment diets

Fatty acid profile[1]	Treatment diets			Mean	SE	P-value[2]
	2.50% CS (control)	11.50% CS	3.13% CS + PL			
SFA	59.11	58.11	57.40	58.21	2.02	0.83
MUFA	42.43	42.63	44.95	43.34	1.68	0.50
PUFA	0.55	0.52	0.40	0.49	0.09	0.49
UFATot	42.99	43.15	45.36	43.83	1.65	0.53
FADes	65.72	63.84	66.53	65.37	1.97	0.62
FAUnd	33.50	34.72	33.73	33.98	1.09	0.70

Note. [1]Fatty acid profile = expressed in% total fatty acid relative area; [2]According to Tukey test ($P < 0.05$); FADes = SFATot + C18:0; FAUnd = C14:0 + C16:0; CS = cottonseed; PL = protected lipid.

Table 7 shows the sensory attributes of the meat as a function of the lipid sources used. Except for the variable tenderness, none the others was not affected when CS levels were increased or PL was added to the diet of the animals (Table 7). The results also showed that animals that received PL in the diet showed greater content of intramuscular fat (Table 4) and reduced tenderness, compared with animals fed 2.50 and 11.50% CS (Table 7).

Table 7. Means for subjective sensory attributes of the meat produced from the different levels of cotton seed inclusion in Nellore cattle

Attributes	Diets			Mean	SE	P-value
	2.50% CS (control)	11.50% CS	3.13% CS + PL			
Aroma intensity	5.23	6.31	5.44	5.66	0.67	0.49
Strange aroma	2.09	2.82	1.91	2.27	0.58	0.51
Taste	6.04	6.41	5.83	6.09	0.68	0.83
Strange taste	1.73	1.91	1.91	1.85	0.39	0.93
Tenderness	5.09[b]	4.36[b]	6.36[a]	5.27	0.43	0.01
Juiciness	5.27	5.73	5.09	5.36	0.41	0.53
Color	4.67	5.65	6.49	5.60	0.71	0.21
General appearance	7.00	7.08	5.37	6.48	0.53	0.05

Note. [ab]Means followed by different letters script in the same rows are significantly different ($P < 0.05$); CS = cotton seed; PL = protected lipid.

4. Discussion

While Costa et al. (2013) observed a linear decrease in EE of the muscle with the addition of CS to the diets of Nellore cattle, a positive correlation between the treatment was found in the present study on protected lipid and intramuscular fat. This finding shows greater efficiency of PL in the passage through the rumen towards the abomasum. In the acid conditions of the abomasum, the chemical bonds of PL are weakened, enabling its degradation and absorption in the small intestine and, later on, its accumulation as intramuscular fat. Although this increase in intramuscular fat was not observed, it improves meat quality, once there was no increase in UFA in the meat.

Several authors (Andrade, 2014; Fiorentini et al. 2012; Souza et al. 2007) observed that the lipid sources in the diet did not change most of the FA in cattle meat. According to Patil et al. (1993), when ruminants are fed high concentrations of fat, either partially or completely protected from the microbial action of the rumen, there may be an increase in percent intramuscular fat and changes in the fatty acid profile. However, the same authors mentioned that these are small changes, which may explain the absence of difference of FA profile in the PL treatment compared with the other lipid sources.

The observed higher values of C18:0 in the meat of the animals that were fed 11.50% CS in the diet were closer to those reported by Costa et al. (2013), who used 14.35% CS in the feed of the animals. Stearic acid, when consumed by humans, is absorbed in the intestines and transported to the liver by chylomicrons. In the liver, it is transformed in oleic acid (monounsaturated), going back to the circulation without cardiovascular risks (Monegaglia & Beyruti, 2004).

The observed results are contrary to those reported by Silva et al. (2009), who observed little or none effects of inclusion of CSFA in the diets on the fatty acid composition in the meat. Greater concentration of PUFA (10.40%) that was observed in the ingredient (CSFA) by Silva et al. (2009), compared with the reduced value (2.96%) of these acids in the PL (ingredient) of the present study, certainly collaborated with increased PUFA levels observed in the meat and caused by greater ingestion of PUFA by the cattle, leading to increased flow of unsaturated fat into the duodenum. Similar study by Andrade (2014) who fed 60% concentrate in a corn-based diet to confined animals diets containing PL or not, observed reduced PUFA contents in the meat when PL was included in the feed. The quantity of corn-based concentrate may have collaborated for a more acid rumen environment, leading to the dissociation of the protected lipid in the rumen and, consequently, to the saturation of part of the PUFA. This may explain the absence of differences between the treatment in the present study, as the diets were made up with more forage and less corn, creating a less acid rumen environment and increasing

the efficiency in the preservation of the unsaturated fatty acids (UFA) of the protected lipid. A fact that may have collaborated for the absence of greater UFA concentrations in the present study after PL treatment is related to the low UFA concentration in the PL ingredient.

Shibuya (2004) did not note any differences between the treatments in the attributes taste and juiciness when CS (21% in DM) or protected fat (5% in DM) were included in the diet of crossbred steers (Simmental x Brangus).

The observed meat attributes values in the current study might have been caused by many factors including nutritional status attained by the animals at slaughter. The observed higher tenderness in Diet 1 and 2 might be attributed to an increase in collagen solubility and increase level of intramuscular fats in the carcass (Christensen et al., 2000, 2004; Hopkins et al., 2006). It is also anticipated that, the inclusion of CS in the finishing diets increased the availability of muscle protein turnover rate, which might also contributed to the increased tendeness of the meat (Hopkins et al., 2006).Higher tenderness in CS diets also might also had an increase in calpain-calpastatin activities which are very much influenced by rate of protein intake (Ibrahim et al., 2008).

As for tenderness, similar to the present study, the author observed that the animals fed CS as their exclusive source of fat showed more tender meat than those fed PL. This result may be explained by the fact that ruminant diets with high concentrations of partially or completely protected fat may lead to increased levels of intramuscular fat and, in some cases, meat tenderness may be negatively affected (Patil et al., 1993), as observed in the present study.

5. Conclusions

The study demonstrated that the addition of PL in the diets of finishing cattle led to greater levels of intramuscular fat, but to less tender meat than the other treatments.

Animals that were fed only CS as their lipid source had more tender meat. Based on these findings, if tenderness adds value to the product in the market, the farmer should adopt a treatment that contains only CS.

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References

Andrade, E. N., Polizel, N. A., Roça, R. O., Faria, M. H., Resende, F. D., Siqueira, G. R., & Pinheiro, R. S. B. (2014). Beef quality of young Angus × Nellore cattle supplemented with rumen-protected lipids during rearing and fatting periods. *Meat Science, 98*, 591-598. http://dx.doi.org/10.1016/j.meatsci.2014.05.028

Andrade, J. G., Duckett, S. K., Hunt, C. W., Pritchard, G. T., & Owens, F. N. (2001). Effects of feeding high-oil corn to beef steers on carcass characteristics and meat quality. *Journal of Animal Science, 79*, 582-588.

AOAC. (1990). Association of Official Analytical Chemists. *Official methods of analysis* (5th ed.). Arlington: AOAC.

AOAC. (2007). Association of Official Analytical Chemists. *Official methods of analysis* (18th ed.). Maryland: AOAC.

Bertrand, J. A., Sudduth, T. Q., Condon, A., Jenkins, T. C., & Calhoun, M. C. (2005). Nutrient content of whole cottonseed. *Journal of Dairy Science, 88*, 1470-1477. http://dx.doi.org/10.3168/jds.S0022-0302(05)72815-0

Christiansen, M, Larsen, L. M., Ertbjerg, P., & Purslow, P. P. (2004). Effect of proteolytic enzyme activity and heating on the mechanical properties of bovine single muscle fibres. *Meat Science, 86*, 361-369. http://dx.doi.org/10.1016/S0309-1740(03)00122-0

Christiansen, M., Purslow, P. P., & Larsen, L. M. (2000). The effect of cooking temperature on mechanical properties of whole meat, single muscle fibres and perimysial connective tissue. *Meat Science, 55*, 301-307. http://dx.doi.org/10.1016/S0309-1740(99)00157-6

CNCPS. (2000). Cornell Net Carbohydrate and Protein System. *The net carbohydrate and protein system for evaluating herd nutrition and nutrients excretion* (Version 4.0, p. 237). Ithaca.

Costa, D. P. B., Roça, R. O., Costa, Q. P. B., Lanna, D. P. D., Lima, E. S., & Barros, W. M. (2013). Meat characteristics of Nellore steers fed whole cottonseed. *Braz. J. Anim. Sci., 42*, 183-192. http://dx.doi.org/10.1590/S1516-35982013000300006

CQBAL 3.0. (2012). *Chemical composition of foods and Brazilian table of ruminant feed*. Viçosa-MG: UFV.

Retrieved February 7, 2012, from http://cqbal.agropecuaria.ws/webcqbal/apresentacao.htm

Demeyer, D., & Doreau, M. (1999). Targets and procedures for altering ruminant meat and milk lipids. *Proceedings of the Nutrition Society, 58*, 593-607. http://dx.doi.org/10.1017/S0029665199000786

Fiorentini, G., Berchielli, T. T., Santana, M. C. A., Dian, P. H. M., Reis, R. A., Sampaio, A. A. M., & Biehl, M. V. (2012). Qualitative characteristics of meat from confined crossbred heifers fed with lipid sources. *Scientia Agricola, 69*, 336-344. http://dx.doi.org/10.1590/S0103-90162012000500008

French, P., Stanton, C., Lawless, F., O'riordan, E. G., Monahan, F. J., Caffery, P. J., & Moloney, A. P. (2000). Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage or concentrate based diets. *Journal of Animal Science, 78*, 2849-2855.

Hall, M. B. (2000). Calculation of non-structural carbohydrate content of feeds that contain non-protein nitrogen. *P.A-25 (Bulletin, 339)*. Gainesville: University of Florida.

Hartman, L., & Lago, B. C. A. (1973). Rapid preparation of fatty, methyl esters from lipids. *Laboratory Practical, 22*, 457-477.

Hasler, C. M. (1998). Functional foods: their role in disease prevention and health promotion. *Food Technology, 52*, 57-62.

Huerta-Leidenz, N. O., Cross, H. R., Lunt, D. K., Pelton, L. S., Savell, J. W., & Smith, S. B. (1991). Growth, carcass traits, and fatty acid profiles of adipose tissues from steers fed whole cottonseed. *Journal of Animal Science, 69*, 3665-3672.

Ibrahim, R. M., Goll, D. E., Marchello, J. A., Duff, G. C., Thomson, V. F., Mares, S. W., & Ahmad, H. A. (2008). Effect of two dietary concentrate levels on tenderness, calpain and calpastatin activities, and carcass merit in Waguli and Brahman steers. *Journal of Animal Science, 86*, 1426-1433. http://dx.doi.org/10.2527/jas.2007-0618

Jenkins, T. C. (1993). Lipid Metabolism in the Rumen. *Journal of Dairy Science, 76*, 3851-3863. http://dx.doi.org/10.3168/jds.S0022-0302(93)77727-9

Meilgaard, M., Civille, G. V., & Carr, B. T. (1990). *Sensory Evaluation Techniques* (p. 281). Boca Raton: CRC Press.

Mertens, D. R. (2002). Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beaker or crucibles: collaborative study. *Journal of AOAC International, 85*, 1217-1240.

Monegaglia, A. P., & Beyruti, M. (2004). *Estearic acid: Friend or enemy of the heart?* São Paulo: Revista ABESO. Retrieved June 26, 2004, from http://www.abeso.org.br/revista/revista13/chocolate.htm

NRC (National Research Council). (1996). *Nutrient requirements of beef cattle* (7th ed., p. 242). Washington: National Academic Press.

NRC (National Research Council). (2001). *Nutrients requirements of dairy cattle* (7th ed., p. 381). Washington: National Academy of Sciences.

Patil, A. R., Goetsch, A. L., Lewis Jr, P. K., & Heird, C. E. (1993). Effects of suplementing growing steers with high levels of partially hydrogenated tallow on feed intake, digestibility, live weight gain, and carcass characteristics. *Journal of Animal Science, 71*, 2284-2292.

SAS/STAT. (2002). *User's Guide for windows environment* (Version 9.0). SAS Inst. Inc., Cary, USA.

Scollan, N., Hocquette, J. F., Nuernberg, K., Dannenberger, D., Richardson, I., & Moloney, A. (2006). Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. *Meat Science, 74*, 17-33. http://dx.doi.org/10.1016/j.meatsci.2006.05.002

Shibuya, C. M. (2004). *Sensory analysis of meat (m. L. thoracis) of steers finished on dry vs. humid corn with or without protected fat (lactoplus), and lactoplus vs. cottonseed* (p. 87 Thesis, Master's degree in Food Technology). Universidade Estadual de Campinas, Faculdade de Engenharia de Alimentos, Campinas, 2004.

Silva, S. L., Leme, P. R., Putrino, S. M., Pereira, A. S. C., Valinote, A. C., Nogueira Filho, J. C. M., & Lanna, D. P. D. (2009). Fatty acid composition of intramuscular fat from Nellore steers fed dry or high moisture corn and calcium salts of fatty acids. *Livestock Science, 122*, 290-295. http://dx.doi.org/10.1016/j.livsci.2008.09.013

Sniffen, C. J., O'Connor, D. J., Van Soest, P. J., Fox, D. G., & Russel, J. B. (1992). A net carbohydrate and

protein system for evaluating cattle diets: II: carbohydrate and protein availability. *Journal Animal Science, 70*, 3562-3577.

Souza, N. E., Silva, R. R., Prado, I. M., Prado, J. M., Wada, F. Y., & Prado, I. N. (2007). Linseed and canola seed on composition of *longissimus* muscle of heifers in feedlot. *Archivos de Zootecnia, 56*, 863-874.

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant* (2nd ed., p. 476). Ithaca: Cornell University Press.

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*, 3583-3597. http://dx.doi.org/10.3168/jds.S0022-0302(91)78551-2