BUFFALO MEAT FROM ANIMALS FED WITH AGRO INDUSTRIAL PRODUCTS IN EASTERN AMAZON

CARNE BUBALINA DE ANIMAIS ALIMENTADOS COM RESÍDUOS AGROINDUSTRIAIS NO AMAZÔNIA ORIENTAL

Peixoto Joele, M.R.S.[1]*; Lourenço Júnior, J.B.[2]; Lourenço, L.F.H.[3]; Amaral Ribeiro, S.C.[1] and Meller, L.H.[3]

[1]Instituto Federal de Educação do Pará-IFPA. Castanhal. Pará State. Brazil. *reginajoele@hotmail.com
[2]Universidade do Estado do Pará. Belém do Pará. Brazil.
[3]Universidade Federal do Pará. Belem do Pará. Brazil.

ADDITIONAL KEYWORDS

Coconut cake. Fatty acids profile. Nutritional quality. Palm cake.

PALAVRAS CHAVE ADICIONAIS

Perfil de ácidos graxos. Qualidade nutricional. Torta de coco. Torta de dendê.

SUMMARY

The quality of buffalo (*Bubalus bubalis*) meat, finished in a silvopastoral system with feed supplementation in the Amazon, was evaluated. Five crossbred buffaloes were used in each treatment with supplements of two different feeds, elaborated with agroindustrial by-products of coconut or palm oil extraction and a traditional one based on corn and soy. Physical, physical-chemical, microbiological, and sensorial analyses were performed on the *Longissimus dorsi* muscle, and the results were analyzed through the analysis of variance and averages, compared by t-test. The coconut and palm treatments had the largest percentage of saturated fatty acids. On the other hand, the ω6/ω3 ratio were within the healthy dietary standards. According to the results of pH, color, and shear force analyses, the meat was classified into RFN (Red, Firm and Normal) or *ideal* standards. Through subjective and objective analyses, the meat of the treatments was considered tender. The quality of the meat produced is due to the farming system used. Moreover, the use of agro-industrial waste minimizes environmental impact and the cost of animal feed, thus increasing the revenue of the rural worker.

RESUMO

Foi avaliada a qualidade da carne de búfalo *(Bubalus bubalis)*, terminados em um sistema silvopastoril com suplementação alimentar na Amazônia. Cinco búfalos mestiços foram utilizados em cada tratamento alimentados com dois diferentes suplementos, elaborados com subprodutos agroindustriais, coco e dendê após extração do óleo e um tradicional à base de milho e soja. Análises físicas, físico-químicas, microbiológicas e sensoriais foram realizadas no músculo *Longissimus dorsi*, e os resultados foram analisados através da análise de variância e as médias comparadas pelo teste t. Os tratamentos de coco e dendê tiveram o maior percentual de ácidos graxos saturados. No entanto, a razão ω6/ω3 estavam dentro dos padrões alimentares saudáveis. De acordo com os resultados das análises de pH, cor e força de cisalhamento, a carne foi classificada em RFN (Red, Firm e Normal) ou padrões *ideais*. Através de análises subjetivas e objetivas, a carne dos tratamentos foi considerada macia. A qualidade da carne produzida é devido ao sistema de exploração utilizado. Além disso, a utilização de resíduos agro-industrial minimiza o impacto ambiental e os custos de alimentação animal, aumentando assim o rendimento do trabalhador rural.

INTRODUCTION

The buffalo herds in the state of Pará, Brazilian Amazon, and Brazil, in the period

Recibido: 11-12-13. Aceptado: 20-3-14.

from 1970 to 2006, grew by, respectively, 87.73, 89.33 and 84.15 %, and in 2008 represented 62.81 % of the nation's cattle according to the Brazilian Institute of Geography and Statistics. In face of such evolution, it is important for Amazon cattle breeding to become competitive without damaging the environment, while the silvopastoral systems may partially contribute to the ecological gain in order to reduce the problems derived from deforestation and degradation of the Amazon ecosystems. These gains may occur, for instance, by cycling nutrients and water, and they also pose advantages compared to monocultures regarding carbon sequestration and the reduction of greenhouse effect (Carvalho, 1998).

However, it is seen that, in the Eastern Brazilian Amazon, there is a high production of palm tree oils that generates large amounts of agro-industrial by-products that may be used in animal feeding as they are a source of carbohydrates and proteins. The bran from coconut and the palm or palm kernel cake represent an alternative source of animal feed given their cost and availability (EMBRAPA, 2004).

In Brazil, some 90 % of the Brazilian buffalo meat originated from pasture ecosystems were commercialized as cattle meat and treated, in most parts of the country, without a defined standard of identification of its characteristics, mainly regarding quality (Correa and Tramoso, 2004; Jorge, 2004; Andrighetto *et al.*, 2008). Thus, the aim of this paper was to evaluate the quality of the meat from buffaloes finished in a silvopastoral system with food supplements of concentrates elaborated from agro-industrial by-products and to compare them to the traditional feed based on corn and soy.

MATERIAL AND METHODS

The experiment was performed in a silvopastoral system, in the Animal Research Unit *Senador Álvaro Adolpho* (1°28' S and 48°27' W), at Embrapa Eastern Amazon, Belem, state of Para, Brazil, in an area of 5.4 ha divided into five plots, with a central zootechnical facility composed of a covered corral with drinking and mineral supplement troughs. The system used mombaça grass (*Panicum maximum* 'Mombaça'), managed in intensive rotation, in a pasture cycle of thirty days with six days of occupation and twenty-four days of rest, in initial and final capacity rates, respectively, of 3.0 AU (animal unit) and 4.5 AU (Oliveira *et al.*, 2010). African mahogany (*Khaya ivorensis*) and Indian nim trees (*Azadirachta indica*) were planted 4 m apart, which, in the experimental period, shaded some 20 % of the area.

Fifteen whole male buffaloes of similar conformation, crossbred from Murrah and Mediterranean breeds, with average initial weight of 400 kg and approximately 27 month of age, were used. The animals were evaluated for the period of eight months with thirty initial days for adaptation and feeding, with mineralization *ad libitum* and regimen of supplement feeding in the proportion of 1 % of their body weight in three experimental treatments (corn, coconut and palm). The centesimal composition of the feeds is shown in **table I**. The

Table I. *Bromatologic composition[1] of experimental feeds.* (Composição bromatológica das rações experimentais).

	Treatment		
	Corn[2]	Coconut[3]	Palm[4]
Moisture	87.13	91.63	90.97
Crude protein	18.46	18.21	18.89
Neutral detergent fiber	19.83	45.42	63.87
Neutral acid fiber	11.65	28.84	35.84
Ethereal extract	3.64	8.87	11.82

[1]Dry matter basis; [2]63 % corn; 25 % fat-free soy bran; 12 % wheat bran; [3]19 % corn; 70 % coconut cake; 11 % wheat bran; [4]2 % corn; 70 % palm cake; 15 % fat-free soy bran; 13 % wheat bran.

animals were fed every morning in individual stalls to assess their consumptions by weighing the food offered and the leftovers. During the supplementation phase, the animals had an average daily weight gain of 1.0 kg.d^{-1} (± 0.3), with no statistical difference among the treatments.

The animals were kept in a hydro diet for fourteen hours and transported in the early morning to the refrigerated slaughterhouse, in a thirty-minute journey and once again kept in a hydro diet for sixteen hours. Later, they were weighed (live animal weight - LAW) and followed the slaughterhouse's regular line of slaughtering, according to the rules of the Regulation for Industrial and Sanitary Inspection of Animal Products - RIISPOA (Brazil, 1997). The carcasses were sent to cooling for 24 hours in a cold room at a temperature of 2-4 °C.

The right half-carcass was cut and the *Longissimus dorsi* muscle was removed for meat analyses and characterization. After cleaning and removal of the superficial fat, sample preparation was initiated. The portion between the 12^{th} and 10^{th} ribs was cut into 2.5 cm-thick steaks, vacuum-packaged, kept under refrigeration, and maturated for seven days at a temperature of 2 °C for the physical and sensorial analyses. pH was determined for the minced muscle in a benchtop pH meter (HANNA, model HI 3222-01, Philadelphia, PA USA). The meat was then packed in polyethylene bags and frozen at –18 °C, for microbiological and physical-chemical analyses.

The samples were thawed under refrigeration for 24 hours. They were then submitted to thermal treatment in an electric oven (Brastemp, model BOG40AR, São Paulo, Brazil) at a temperature of 180 °C until the internal temperature reached 70 °C so that the analyses were carried out.

For the evaluation of the shear force, eight 1.27 cm-wide cylinders were removed from each steak, parallel to the muscle fibers, and analyzed in a texture meter (Texture Analyzer TA-XT2i, Croydon, Greater London, UK) coupled to a Warner-Bratzler blade, as proposed by Wheeler *et al.* (1996). The water holding capacity was obtained from the difference between the weights of the meat samples before and after being submitted to the pressure of 10 kg for five minutes, while the weight loss due to cooking temperature was calculated from the difference of the weights before and after thermal treatment, expressed as a percentage (Hamm, 1977).

The objective color was established through the L* (light), a* (red/green intensity) and b* (yellow/blue intensity) parameters of the CIELAB System using D65 illumination, 8° viewing angle, and 10° standard observer, as specified by the Comission Internacionale d'le Ecleraige-CIE, with the use of a portable colorimeter (Hunter Lab/MiniScan EZ, Reston, VA, USA). The measurements were performed 30 minutes after the opening of the bags and exposition of the samples to oxygen under refrigeration. The final value was the average of six readings obtained in different pre-defined positions in the same steak. With those averages, chroma C* $[C^* = (a^{*2} + b^{*2})^{1/2}]$ and hue angle $[h^* = \tan^{-1}(b^*/a^*)]$ were calculated, as well as the total difference of color (DE), between corn, coconut and palm treatments, according to Ramos and Gomide (2009):

$$\{DE=[(DL^*)^2+(Da^*)^2+(Db^*)^2]^{1/2}\}$$

Analysis for *Salmonella spp.* was performed in a 25 g sample, in an indicative form, according to the current Brazilian Legislation for *in natura* meat (Brazil, 2001), a methodology described in Downes and Ito (2001).

In order to determine the centesimal composition of the *Longisssimus dorsi* muscle, the analyses of moisture, ash, total proteins, and ether extract followed the methodology of the Association of Official Analytical Chemists (AOAC, 1990 a, b). The carbohydrates were obtained from the difference and the caloric value determined according to the energetic value of the proteins, lipids, and carbohydrates.

For the analysis of the fatty acids profiles, the samples were lyophilized for later cold fat extraction and acid etherification, performed according to the methodology from AOCS (2002). The reading of the ethers was performed in a gas chromatograph (VARIAN model CP 3380, Snoqualmie, WA, USA), equipped with a flame ionization detector and fused silica capillary column model CP-Sil 88 (60 m x 0,25 mm). 1µl of the sample was injected with a split system at a ratio of 1:50, using helium as a carrier gas at a flow of 1 mL/minute. The temperature of the injector was 245 °C and the detector's was 280 °C, with 45 minutes total time for the analyses. As a standard, a 68D solution (NU CHECK- Elysian, MN, USA) was used, which has a certified value for 20 fatty acids in order to establish the correction factors in each one of the certified fatty acids. The fatty acids were quantified as a relative percentage of the area of peaks found and the calculations were performed according to Equation 1:

$$\%\ Relative\ area\ of\ fatty\ acids = \frac{area\ of\ fatty\ acids\ x\ 100}{total\ area\ of\ fatty\ acids}$$

The sensory profiles of the samples were determined according to Stone *et al.* (1974). The team of thirty trained tasters evaluated the samples in a monadic way in triplicate in a non-structured scale of 9 cm. The following attributes were analyzed: characteristic meat aroma, characteristic meat taste, liver taste, fat taste, tenderness, juiceness, and liver texture. The tests were performed in individual computerized booths using as a tool the Fizz Sensory Analysis Software (version 2.4 H - Biosystemes, Dijon, France).

The thermal treatment of the samples was performed as previously described and they were later cut into 4 cm^2 pieces, wrapped in aluminum paper, and kept hot in bain marie at a temperature of 60 °C until they were served to the tasters.

A completely randomized experimental design was used where each animal represented one experimental unit. Initially, the normality of data distribution was tested and all variables met the normality fit without the need for data transformation. In order to evaluate the effect of supplement feeding on the Silvopastoral System (corn, coconut, and palm), the data were submitted to the analysis of variance and the averages were compared through t-test, at 5 % of significance, with the software Statistica 5.0.

RESULTS AND DISCUSSION

The diets had little influence on the analyzed physical variables **(table II)**, with significant effect just for the parameter of color (b*) and weight loss due to cooking temperature ($p<0.05$).

The values of pH are similar to the ones reported by Jorge *et al.* (2006) and Spanghero *et al.* (2004), when evaluating different buffalo muscles (5.43; 5.46, and 5.47, respectively, for each treatment). The values found were considered low, a fact attributed to the docile attitude of the buffaloes that suffer less stress at slaughter and muscular glycogen exhaustion, which diminishes the possibility of DFD (dark, firm, dry) meat. According to Roça (1997), the final pH of 6.0 is the limit between the normal cut and the typical darkness of DFD meat.

No significant differences were found for shear force **(table II)** due to feeding, with values that are similar to the ones described by Andrighetto *et al.* (2008) when analyzing Mediterranean buffaloes, and to the ones found by Jorge *et al.* (2005), when evaluating animals with different weights at slaughter. They may be classified as tender meat, with shear force values below 5.0 kgf established by Felício (1997) as the limit for the meat to have appropriate tenderness.

The value for b* was higher in the samples from the palm treatment. The raise in red intensity is associated to the yellow one, which may be due to the sensitivity of the heme pigments to oxidation and/or to the carotenoids pigments being anti-oxidants (Mancini and Hunt, 2005). The average values of luminosity are within the variation considered ideal (from 34 to 39) for the *Longissimus dorsi* muscle of oxen (Purchas *et al.*, 2002), however, the intensity of red color (a*) is below the one indicated by these authors (from 18 to 22). This may be due to the low marbling of buffaloes as well as the concentration of myoglobine related to a larger metabolic function of oxygen in the animal's development. Jorge *et al.* (2006) found similar values for the objective color in Mediterranean breed buffaloes with different weights at slaughtering.

The sample from the palm treatment had a higher total color difference and, according to Prãndl *et al.* (1994), this difference is of a *very clear* perception (DE* between 3.0 and 6.0), whilst the sample of the coconut treatment had a total color difference considered *clear* (DE* between 1.5 and 3.0).

It was also verified that the hue angle (h*) for all samples ranged from 0.62° to 0.73°, that is, within the band of red color. According to Ramos and Gomide (2009), the interpretation of the hue differences, in the solid as a whole, may be done as follows: red (330 to 25°), orange (25 to 70°), yellow (70 to 100°), green (100 to 200°), blue (200 to 295°), and violet (295 to 330°).

The C* and h* values for the palm treatment were higher when compared to the other ones. These parameters are functions of a* and b* and allow to determine the intensity of the color, its saturation, or to estimate the real meat darkening and, normally, the meat's discoloration process and is followed by a raise in the C* and h* values over time (Lee *et al.*, 2005).

The samples of the coconut treatment had higher weight loss due to cooking temperature ($p<0.05$) in the *Longissimus dorsi* muscle when compared to the other treatments. Similar results were found by Vaz *et al.* (2003) and Spanghero *et al.* (2004) with Mediterranean breed buffaloes.

Table II. *Average, standard deviation, and coefficient of variance of the physical characteristics of buffalo meat of animals finished in a silvopastoral system, according to supplementation.* (Média, desvio padrão e coeficiente de variação das características físicas da carne de búfalos alimentados em sistema silvopastoril, de acordo com a suplementação alimentar).

Analysis	Treatment			CV (%)
	Corn	Coconut	Palm	
pH	5.48^{a} ± 0.026	5.45^{a} ± 0.035	5.47^{a} ± 0.036	0.46
SF[1] (kgf)	3.93^{a} ± 1.138	4.61^{a} ± 0.978	3.81^{a} ± 0.365	18.91
L*	33.32^{a} ± 3.182	35.66^{a} ± 2.979	38.28^{a} ± 1.609	6.63
a*	15.74^{a} ± 1.378	15.94^{a} ± 1.172	16.13^{a} ± 2.792	1.27
b*	11.34^{a} ± 2.095	12.89^{ab} ± 1.120	14.57^{b} ± 1.315	9.32
AE	-	2.81	5.96	
C*	19.40	20.50	21.89	
h *	0.62	0.68	0.73	
WHC[2] (%)	69.34^{a} ± 2.135	72.57^{a} ± 1.956	73.33^{a} ± 6.672	4.08
WLC[3] (%)	25.74^{a} ± 1.664	34.29^{b} ± 3.446	28.08^{a} ± 1.543	10.78

[ab]Averages followed by different letters on the same line have significant differences among one another ($p<0.05$).
[1]Shear force; [2]Water holding capacity; [3]Weight loss due to cooking.

The samples of the *Longissimus dorsi* muscle indicate absence of *Salmonella spp.*, being considered appropriate for human consumption according to the Brazilian legislation (Brazil, 2001).

Significant differences were found in the contents of lipids, ashes, and caloric value in the *Longissimus dorsi* muscle of the experimental animals due to supplementation feeding **(table III)**.

There was no influence (p>0.05) of animal feeding on moisture and on the contents of proteins and carbohydrates of the *Longissimus dorsi* muscle. The lipid content was higher in the coconut and palm treatments (p<0.05) due to the high contents of ethereal extract and neutral detergent fiber of the feed **(table I)**, which is reflected on its caloric value.

The values found for moisture and proteins are in accordance to the ones obtained by Menegucci *et al.* (2006), in Murrah buffaloes, while the values of lipids and ashes, in all three treatments, are higher to the ones described by these authors. The caloric value found in this paper is lower than the one described by Menegucci *et al.* (2006) for buffaloes, and than the ones mentioned in the tables of food composition consumed in Brazil, developed by the Center for Studies and Research in Food (NEPA, 2004).

The samples of the *Longissimus dorsi* muscle analyzed **(table IV)** had a percentage of fatty acids similar to the ones determined by Luccia *et al.* (2003), Lira *et al.* (2005), and Oliveira *et al.* (2008) for buffalo meat, as well as French *et al.* (2000), Noci *et al.* (2005), and Garcia *et al.* (2008) for beef from oxen supplemented with oleaginous plants.

Most of the fatty acids in mammals are saturated, mainly palmitic and estearic acids (Price and Schweigert, 1994; Pardi *et al.*, 2001). Banskalieva *et al.* (2000) showed that palmitic acid (C16:0) raises blood cholesterol and estearic acid (C18:0) has no effect on the LDL fraction and human diets with elevated levels of lauric, miristic, and palmitic acids are hypercholesterolemic.

The muscle from the animals in the corn treatment had a lower percentage of saturated fatty acids on average when compared to the other treatments (p<0.05), probably influenced by feeding, as the feed has a low content of these acids when compared to the other ones (p<0.05). The saturated fatty acids which were found at a higher concentration in all treatments were palmitic (C16:0) and estearic (C18:0), with significant differences among the treatments. The corn treatment had a lower palmitic acid content when compared to the other ones, a desirable fact for meat. In the

Table III. *Average, standard deviation, and coefficient of variation of the centesimal composition of the buffalo meat from animals finished in a silvopastoral system, according to the treatments.* (Média, desvio padrão e coeficiente de variação da composição centesimal da carne de búfalos terminados em sistema silvopastoril, de acordo com o tratamento).

Analysis DM basis	Treatment Corn	Coconut	Palm	CV (%)
Moisture (%)	74.02[a] ± 1.772	73.00[a] ± 0.081	72.98[a] ± 0.889	1.40
Protein (%)	21.05[a] ± 1.037	21.21[a] ± 1.325	21.43[a] ± 0.782	4.87
Lipid (%)	2.07[a] ± 0.239	2.35[b] ± 0.199	2.45[b] ± 0.118	17.70
Ash (%)	1.82[a] ± 0.299	1.69[ab] ± 0.249	1.33[b] ± 0.147	17.70
Carbohydrate (%)	1.04[a] ± 0.399	1.75[a] ± 0.284	1.80[a] ± 0.226	16.68
Caloric value (kcal/100 g)	106.98[a] ± 7.087	113.00[b] ± 0.322	115.01[b] ± 3.555	3.55

[ab]Averages followed by different letters on the same line have significant differences (p<0.05).

Table IV. *Most important fatty acids detected in the feed and the* Longissimus dorsi *muscle from animals finished in silvopastoral system, according to the type of supplementation.* (Ácidos graxos mais importantes detectados no músculo *Longissimus dorsi* de animais finalizados em sistema silvopastoril de acordo com o tipo de alimentação).

	Feed			Muscle			CV
	Corn	Coconut	Palm	Corn	Coconut	Palm	(%)
Lipids (%)	3.64	8.87	11.82	$2.07^{a} \pm 0.239$	$2.35^{b} \pm 0.199$	$2.45^{b} \pm 0.118$	17.702
C12:0	0.40^{A}	3.72^{A}	58.13^{B}	-	-	-	-
C14:0	-	14.01^{A}	12.91^{A}	$3.63^{a} \pm 1.988$	$10.16^{b} \pm 0.526$	$11.04^{b} \pm 2.250$	36.604
C14:1	-	-	-	$0.56^{a} \pm 0.212$	$1.61^{ab} \pm 0.163$	$2.11^{b} \pm 0.049$	39.086
C16:0	15.05^{A}	30.44^{C}	5.11^{B}	$26.23^{b} \pm 1.871$	$30.42^{a} \pm 0.156$	$31.37^{a} \pm 0.310$	7.771
C16:1	-	3.91	-	$2.25^{a} \pm 0.954$	$3.50^{a} \pm 0.785$	$3.65^{a} \pm 0.092$	23.940
C18:0	-	8.30	0.80	$13.92^{ab} \pm 1.215$	$14.28^{b} \pm 0.370$	$12.15^{a} \pm 0.932$	10.699
C18:1	22.53^{B}	32.07^{C}	8.02^{A}	$38.84^{b} \pm 3.037$	$34.55^{a} \pm 1.725$	$35.26^{a} \pm 0.848$	6.621
C18:2	57.21^{B}	5.76^{A}	6.22^{A}	$5.78^{a} \pm 1.157$	$7.98^{b} \pm 1.707$	$4.98^{a} \pm 1.824$	39.013
C18:3	-	-	-	$0.48^{a} \pm 0.021$	$0.36^{a} \pm 0.021$	$0.60^{b} \pm 0.056$	21.491
C20:1	-	-	-	$0.74^{a} \pm 0.316$	$3.42^{b} \pm 0.458$	$0.60^{a} \pm 0.047$	57.628
SFA	20.26^{A}	58.26^{B}	85.76^{C}	$37.54^{a} \pm 16.052$	$52.29^{b} \pm 7.849$	$54.57^{b} \pm 1.269$	18.061
MUFA	22.53^{B}	35.99^{C}	8.02^{A}	$41.94^{a} \pm 4.370$	$40.14^{a} \pm 2.950$	$39.87^{a} \pm 1.170$	6.286
PUFA	57.21^{A}	5.76^{B}	6.22^{B}	$6.15^{a} \pm 1.002$	$5.60^{a} \pm 1.849$	$5.23^{a} \pm 1.269$	22.845
S/U	0.25^{A}	1.39^{A}	6.02^{B}	$2.08^{a} \pm 0.264$	$1.14^{a} \pm 0.251$	$1.19^{a} \pm 0.061$	49.618
ω6/ω3 ratio	0.39^{A}	5.57^{C}	1.29^{B}	$7.78^{a} \pm 0.014$	$8.20^{a} \pm 0.083$	$7.74^{a} \pm 0.054$	16.685

C12:0-Lauric; C14:0-Miristic; C14:1-Miristoleic ω9; C16:0-Palmitic; C16:1-Palmitoleic; C18:0-Estearic; C18:1-Oleic ω9; C18:2-Linoleic ω6; C18:3-Linolenic ω3; C20:1-Eicosamonoeinoic ω9; SFA= saturated fatty acids; MUFA= monounsaturated fatty acids; PUFA= polyunsaturated fatty acids; S/U= saturated/ unsaturated relation.

^{ABC,ab}Averages followed by different letters on the same line have significant differences (p<0.05).

case of estearic acid, considered a neutral fatty acid, a significant difference was found in the meat of the palm treatment, which had a lower percentage compared to a higher one in the corn treatment, which reflects on the deposition of such acid as the feed has a high content of this component.

The values for oleic acid, the main monounsaturated fatty acid, were higher (p<0.05) in the corn treatment (38.84 %). These levels were similar to the ones reported by Rodrigues *et al.* (2004), Fonseca *et al.* (2005), and Oliveira *et al.* (2008), but higher than the one reported by Lira *et al.* (2005). The content of eicosanoic acid (C20:1), another monounsaturated acid of great importance to human health due to its long chain in spite of its quantitatively low percentage, was higher in the coconut treatment (p<0.05). It is important to highlight that this important acid, rarely detected in ruminant meat and much more common in fish, regulate the polyunsaturated:saturated ratio and, therefore, is responsible for beneficial effects for preventing cardiovascular disorders.

The polyunsaturated fatty acid found in highest concentrations in all treatments was the linoleic acid, with the highest percentage in the meat of the coconut treatment (p<0.05), higher than the ones observed by Rodrigues *et al.* (2004) and Oliveira *et al.* (2008), and similar to the ones found by Sinclair *et al.* (1982) and Lira *et al.* (2005). According to

Funck *et al.* (2006), linoleic acid may be converted into C18:2 trans-10/cis-12 and C18:2 cis-9/trans-11 isomers through the action of the *Propionibacter* bacterium, while Bauman and Griinari (2001) report that the C18:2 cis-9/trans-11 isomer predominates in ruminant meat as it is an intermediate actor of ruminant biohydrogenation of the linoleic acid, besides having a higher anticarcinogenic potential. In that case, it is seen that the percentage of linoleic acid in the feed was not directly absorbed by the animal, as the corn feed had a high content of this component.

The amount of linoleic acid detected in the samples ranged from 4.98 to 7.98 % and, considering that in ruminants 57 to 85 % of these are cis-9/trans-11 isomers, it is possible to infer that the buffalo meat from the experimental treatments had a value of CLA (conjugated linoleic acid) between 3.29 to 4.81 %, which is considered very good since, in order to obtain beneficial biological effects, an average human being (70 kg) would need to consume approximately 5 g of CLA a day, that is, a meat portion of 200 g (Simopoulos, 1991).

The ω6:ω3 ratio found in the meat of animals from the three experimental treatments did not have any significant difference. According to the literature (NRC, 1996; Schaefer, 2002) the ideal ratio is 2:1, however, the recommendation from the Recommended Dietary Allowances (RDA, 2005) is from 5 to 10:1. Thus, the results are still within the healthy dietary standards. The polyunsaturated fatty acids from ω6 and ω3 series may be effective in cholesterol reduction when compared to the saturated ones, while the ω3 ones reduce the LDL cholesterol and may raise the HDL fraction as well as lower the triglycerides levels in the blood.

No significant differences were found in the saturated:unsaturated fatty acids ratio, a result similar to the one obtained by Oliveira *et al.* (2008), with the inclusion of soy oil in the diet of Murrah buffaloes. However, the unsaturated:saturated acids ratio must be improved in the corn, coconut, and palm treatments as they are below the minimum recommended for the total diet (0.45) by the British Department of Health. Studies have reported that supplementation with sources of polyunsaturated and monounsaturated fatty acids in ruminant feeding have been efficiently incorporated into the meat (Palmiquist, 1991; Enser *et al.*, 1999; Moloney *et al.*, 2001).

No significant differences were found

Table V. *Sensory profile of the* Longissimus dorsi *muscle of animals finished in a silvopastoral system, according to supplementation\concentrate.* (Perfil sensorial do músculo *Longissimus dorsi* de animais finalizados em sistema silvopastoril, de acordo com a suplementação alimentar).

Parameter	Treatment			CV
	Corn	Coconut	Palm	(%)
Characteristic meat smell	5.51[a] ± 0.551	5.86[a] ± 0.371	5.81[a] ± 0.451	5.11
Characteristic meat taste	6.56[a] ± 0.172	6.46[a] ± 0.242	5.06[a] ± 0.462	6.57
Fat taste	1.38[a] ± 0.493	1.39[a] ± 0.431	1.96[a] ± 0.531	15.82
Liver taste	0.78[a] ± 0.962	0.84[a] ± 0.415	1.08[a] ± 0.223	10.75
Tenderness	6.03[a] ± 0.721	5.90[a] ± 0.832	6.21[a] ± 0.412	8.78
Juicyness	5.39[a] ± 0.371	5.07[a] ± 0.675	5.33[a] ± 0.935	10.97
Liver texture	1.15[a] ± 0.455	1.11[a] ± 0.431	1.38[a] ± 0.101	23.06

[ab]Averages followed by different letters on the same line have significant differences among one another ($p<0.05$).

(p>0.05) among the treatments regarding the sensory standards evaluated in the panel **(table V)**. Andrighetto *et al.* (2008), when evaluating taste, smell, tenderness, and juiceness of Murrah buffalo meat, also did not find any significant differences among these characteristics.

The values obtained for subjective tenderness and shear force of the samples indicated that the meat is tender. The evaluation of juiceness received grades little above the average, being considered little juicy. Such result may have been impaired due to the low content of intramuscular fat **(table III)**, as the higher the fat content, the better the sensation of juiceness of the meat (Cross, 1994; Roça, 1997).

CONCLUSION

The evaluation of the meat from animals supplemented with different types of feed did not have a large variation in its physical, chemical, and sensory characteristics. All samples, according to the results of the analyses of pH, color, and shear force, are within the parameters for *ideal* meat or *RFN*, with good sensory evaluation and microbiologically appropriate for human consumption. However, the evaluation of the fatty acids profiles shows that the meats from coconut and palm treatments had a higher percentage of miristic (C14:0) and palmitic (C16:0) acids, considered hypercholesterolemic, as well as a higher percentage of saturated fatty acids (SFA). The meats from the coconut treatment had a higher percentage of estearic acid, which is a neutral fatty acid, and linoleic acid (C18:2), and have beneficial effects to human health. The meats from coconut, corn, and palm treatments were considered tender according to the shear force and subjective tenderness.

ACKNOWLEDGEMENTS

Authors thank to Federal Institute for Education, Science and Technology - IFPA, Embrapa Eastern Amazon (Animal Biotec Network; code 01.07.01.02.09.05), Federal Rural University of Amazônia-UFRA, Brazilian National Council for Scientific and Technological Development (CNPq; process 481837/2007-8), CAPES/FAPESPA, for financial support.

REFERENCES

Andrighetto, C.; Jorge, A.M.; Roça, R.O.; Rodrigues, E.; Bianchini, W. e Francisco, C.L. 2008. Características físico-químicas e sensoriais da carne de bubalinos Murrah abatidos em diferentes períodos de confinamento. *Rev Bras Zootecn,* 37: 2179-2184.

AOAC. 1990a. Official methods of analysis. 15th ed. Official method 960.39. Assoc. Off. Anal. Chem. Arlington, VA.

AOAC. 1990b. Official methods of analysis. 15th ed. Official method 950.46. Assoc. Off. Anal. Chem. Arlington, VA.

AOCS. 2002. Official methods and recommended practices of de AOCS. 15th ed. Ass. Oil Chem. Soc. Champaign, IL.

Banskalieva, V.; Sahlu, T. and Goetsch, A.L. 2000. Fatty acid composition fat depots: a review. *Small Ruminant Res*, 37: 255-268.

Bauman, D.E. and Griinari, J.M. 2001. Regulation and nutritional manipulation of milk fat: low-fat milk syndrome. *Livest Prod Sci,* 70: 15-29.

Brazil. 1997. Ministério da Agricultura. Departamento Nacional de Inspeção de Produtos de Origem Animal. Regulamento da inspeção industrial e sanitária de produtos de origem animal-RIISPOA. Brasília, DF.

Brazil. 2001. Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Regulamento técnico sobre os padrões microbiológicos para alimentos. RDC nº 12, de 02/01/2001. Brasília, DF.

Carvalho, M.M. 1998. Arborização de pastagens cultivadas. EMBRAPA-CNPGL (Documento 64). Juiz de Fora, MG. 37 pp.

Correa, A. and Tramoso, E. 2004. Búfalos. *Rev Produz,* 1: 36-43.

Cross, H.R. 1994. Características organolépticas de la carne. In: J.F. Price and B.S. Schweirgert (Eds). Ciência de la carne y de los productos carneos. Acribia. Zaragoza. pp. 279-294.

Downes, F.P. and Ito, K. 2001. Compendium of methods for the microbiological. Examinations of Foods. 4th ed. APHA. Washington, DC.

EMBRAPA. 2004. Biodegradação da fibra da casca de coco. http://www.catalogosnt.cnptia.embrapa.br/catalogo20/catalogo_de_produtos_e_servicos/arvore/CONTAG01_520_24112006153314.html (21/09/2008).

Enser, M.; Scollan, N.D.; Choi, N.J.; Kurt, E.; Hallett, K. and Wood, J.D. 1999. Effect of dietary lipid on the content of conjugated linoleic acid (CLA) in beef muscle. *Anim Sci,* 69: 143-146.

Felício, P.E. 1997. Fatores que influenciam na qualidade da carne bovina. In: A.M. Peixoto and J.C. Moura (Eds.). Produção de Novilho de Corte. FEALQ. Piracicaba. pp. 79-97.

Fonseca, D.M.; Prado, I.N.; Vicenta, J.V.; Matsushita, V.I. and Souza, N.E. 2005. *Longissimus dorsi* chemical composition and fatty acid profile in Murrah buffalo (*Bubalus bubalis*) heifers fattened in drylot with hormonal implantation and lead spheres in the uterus. *J Anim Veter,* 4: 462-466.

French, P.; Stanton, C.; Lawless, F.; O'riordan, E.G.; Monahan, F.J., Caffrey, P.J. and Moloney, A.P. 2000. Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazes grass, grass silage, or concentrate-based diets. *J Anim Sci,* 78: 2849-2855.

Funck, L.G.; Barrera-Arellano, D. e Block, J.M. 2006. Ácido linoleico conjugado (CLA) e sua relação com a doença cardiovascular e os fatores de risco associados. *Arch Latinoam Nutr,* 56: 51-63.

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

Hamm, R. 1977. Physical, chemical and biological changes in food caused by thermal processing (1th ed.). Applied Science Publishers. London. 101 pp.

Jorge, A.M. 2004. Produção de carne bubalina. Simposio de búfalos de Las Américas, 2. Proceedings... Charlas. Universidad Nacional del Nordeste. Corrientes. Argentina. Vol. 1. pp. 1-25.

Jorge, A.M.; Andrighetto, C.; Millen, D.D.; Calixto, M. e Vargas, A.D.F. 2005. Características quantitativas da carcaça de bubalinos de três grupos genéticos terminados em confinamento e abatidos em diferentes estádios de maturidade. *Rev Bras Zootecn*, 34: 2376-2381.

Jorge, A.M.; Andrighetto, C.; Millen, D.D.; Calixto, M.; Rodrigues, E.; Storti, S.M.M. and Vilela, L.C. 2006. Biochemicals meat traits from Mediterranean buffaloes finished in feedlot and slaughtered at different weights. *Ciênc Rural,* 36: 252-257.

Lee, S.; Decker, E.A. and Faustman, C. 2005. The effects of antioxidants combination on color and lipids oxidation in n-3 oil fortified ground beef parties. *Meat Sci*, 70: 683-689.

Lira, G.M.; Mancini Filho, J.; Torres, R.P.; Oliveira, A.C., Vasconcelos, A.M.A.; Omena, C.M.B. and Almeida, M.C.S. 2005. Centesimal composition, caloric value, level of cholesterol, and fatty acid profile of the meat from buffalo (*Bubalis bubalis*) breeding in the area of São Luiz do Quitunde-AL. *Rev Inst Adolfo Lutz,* 64: 31-38.

Luccia, A.D.; Satriani, A.; Barone, C.M.A.; Colatruglio, P.; Gigli, S.; Occidente, M.; Trivellone, E.; Zullo, A. and Matassino, D. 2003. Effect of dietary energy content on the intramuscular fat depots and triglyceride composition of river buffalo meat. *Meat Sci*, 65: 1379-1389.

Mancini, R.A. and Hunt, M.C. 2005. Review: Current research in meat color. *Meat Sci,* 71: 100-121.

Menegucci, P.F.N.; Jorge, A.M.; Andrighetto, C.; Athayde, N.B.; Francisco, C.E.L.; Rodrigues, E. e Storti, S.M.M. 2006. Rendimento de carcaça, dos cortes comerciais e da porção comestível de bubalinos Murrah castrados abatidos com diferentes períodos de confinamento. *Rev Bras Zootecn,* 35: 2427-2433.

Moloney, A.P.; Mooney, M.T.; Kerry, J.P. and Troy, D.J. 2001. Producing tender and flavoursome beef with enhanced nutritional characteristics. *Proc Nutr Soc,* 60: 221-229.

NEPA. 2004. Núcleo de Estudos e Pesquisa em Alimentação. Tabela brasileira de composição de alimentos, 1. UNICAMP. Campinas. São Paulo. 44 pp.

Noci, F.; O'kiely, P.; Monahan, F.J.; Stanton, C. and Moloney, A.P. 2005. Conjugated linoleic acid concent feed in M. *Longissimus dorsi* from heifers offered sunflower oil-based concentrates and conserved forages. *Meat Sci*, 69: 509-518.

NRC. 1996. Nutrient Research Council. Carcinogens and anticarcinogens in the human diet. National Academy Press. Washington, DC.

Oliveira, R.L.; Ladeira, M.M.; Barbosa, M.A.A.F.; Assunção, D.M.P.; Matsushita, M.; Santos, G.T. e Oliveira, A.L. 2008. Ácido linoleico conjugado e perfil de ácidos graxos no músculo e na capa de gordura de novilhos bubalinos alimentados com diferentes fontes de lipídios. *Arq Bras Med Vet Zootec,* 60: 169-178.

Oliveira, K.C.C.; Faturi, C.; Garcia, A.R.; Nahúm, B.S.; Lourenço Júnior, J.B. and Peixoto Joele, M.R.S. 2010. Supplemental feeding for buffaloes with agroindustry by-products on silvipastoral system in Brazilian Eastern Amazon. *Rev Vet,* 21: 809-811.

Palmiquist, D.L. 1991. Influence of source and amount of dietary fat on digestibility in lactating cows. *J Dairy Sci*, 74: 1354-1360.

Prãndl, O.; Fischer, A.; Schimidhofer, T. and Sinnel, H. 1994. Tecnología de higiene de la carne. Acribia. Zaragoza.

Pardi, M.C.; Santos, I.F.; Souza, E.R. e Pardi, H.S. 2001. Ciência, higiene e tecnologia da carne. 2.ª ed. Centro Editorial e Gráfico Universidade de Goiás. Goiânia.

Price, J.F. y Schweigert, B.S. 1994. Ciencia de la carne y de los productos cárnicos. 2.ª ed. Acribia. Zaragoza.

Purchas, R.W.; Burnham, D.L. and Morris, S.T. 2002. Effects of growth potential and growth path on tenderness of beef *Longissimus* muscle from bulls and steers. *J Anim Sci*, 80: 3211-3221.

Ramos, E.M. e Gomide, L.A.M. 2009. Avaliação da qualidade de carnes: fundamentos e metodologias. Editora UFV. 599 pp.

RDA. 2005. Recommended dietary allowances. National Academy of Sciences. 10th ed. Washington, DC.

Roça, R.O. 1997. Tecnologia da carne e produtos derivados. Departamento de Gestão e Tecnologia Agroindustrial. FCA. UNESP. Botucatu. São Paulo.

Rodrigues, V.C.; Bressan, M.C.; Cardoso, M.G. e Freitas, R.T.F. 2004. Ácidos graxos na carne de búfalos e bovinos castrados e inteiros. *Rev Bras Zootecn,* 33: 434-443.

Schaefer, E.J. 2002. Lipoproteins, nutrition, and heart disease. *Am J Clin Nutr,* 75: 191-212.

Simopoulos, A.P. 1991. Omega-3 - fatty acids in health and disease and in growth and development. *Am J Clin Nutr,* 54: 438-463.

Sinclair, A.J.; Slattery, W.J. and O'dea, K. 1982. The analysis of polyunsaturated fatty acids in meat by capillary gas-liquid chromatography. *J Sci Food Agr,* 33: 771-776.

Spanghero, M.; Gracco, L.; Valusso, R. and Piasentier, E. 2004. *In vivo* performance, slaughtering traits and meat quality of bovine (Italian Simmental) and buffalo (Italian Mediterranean) bulls. *Livest Prod Sci,* 7: 1-13.

Stone, H.; Sidel, J.; Oliver, S.; Woolsey, A. and Singleton, R.C. 1974. Sensory evaluation by quantitative descriptive analysis. *Food Technol,* 28: 24-34.

Vaz, F.N.; Restle, J.; Brondani, I.L. e Pacheco, P.S. 2003. Estudo da carcaça e da carne de bubalinos Mediterrâneo terminados em confinamento com diferentes fontes de volumoso. *Rev Bras Zootecn,* 32: 393-404.

Wheeler, T.L.; Koohmaraie, M. and Shackelford, S.D. 1996. Standardized Warner-Bratzler shear force procedures for meat tenderness measurement. U.S. MARC. Clay Center. Roman L. Hruska. USDA.