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Total lipid nutritional quality of the adipose tissue from the orbital cavity in Nile tilapia from continental aquaculture

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ABSTRACT. This study aimed to determine the fatty acid composition and nutritional quality indexes of total lipids in adipose tissue from the orbital cavity of Nile tilapia from continental aquaculture in Paraiba State, Brazil. The tilapias were captured in six fish farms, and after slaughtering and bleeding, the adipose tissue from the orbital cavity was reserved, frozen and lyophilized for analysis of fatty acid composition by gas chromatography. By decreasing order, oleic, palmitic, linoleic, stearic, and palmitoleic acids were the most abundant ones. Monounsaturated fatty acids were the most prominent group in orbital cavity adipose tissue, where as polyunsaturated fatty acids were most abundant in the diet, with a percentage of linolenic acid ranging from 32.99 to 37.57%. Nutritional quality indexes of lipids varied from 0.491 to 0.575 for Atherogenicity Index, 0.543 to 0.741 for Thrombogenicity Index, and from 1.918 to 2.176 regarding the ratio of hypocholesterolemic/hypercholesterolemic. According to the composition of fatty acids and the nutritional quality of total lipids, the use of this byproduct can be recommended for human consumption or to elaborate products for animal intake.

Keywords: fatty acids, atherogenicity index, thrombogenicity index, *Oreochromis niloticus*.

Qualidade nutricional dos lipídios totais no tecido adiposo da cavidade ocular da tilápia do Nilo da aquicultura continental

RESUMO. O objetivo deste estudo foi determinar a composição dos ácidos graxos e os índices de qualidade nutricional dos lipídios totais no tecido adiposo da tilápia do Nilo da aquicultura continental do Estado da Paraíba, Brasil. As tilápias foram capturadas em seis pisciculturas. Após o abate e sangria, o tecido adiposo da cavidade ocular foi reservado, congelado e liofilizado para análise da composição de ácidos graxos por cromatografia gasosa. Os ácidos graxos majoritários detectados em ordem decrescente foram: ácido oleico, ácido palmítico, ácido linoleico, ácido esteárico e ácido palmitoleico. O grupo mais abundante no tecido adiposo da cavidade ocular foi o dos ácidos graxos monoinsaturados, enquanto que na ração o grupo mais abundante foi o grupo dos ácidos graxos poli-insaturados, com percentual do ácido linolênico variando entre 32,99 e 37,57%. Os índices de qualidade nutricional dos lipídios variaram de 0,491 a 0,575 para o Índice de Aterogenicidade, 0,543 a 0,741 para o Índice de Trombogenicidade; e 1,918 até 2,176 para a razão entre hipocolesterolêmicos / hipercolesterolêmicos. De acordo com a composição dos ácidos graxos e a qualidade nutricional dos lipídios totais, é possível recomendar o uso deste subproduto para o consumo humano ou elaborar produtos para consumo animal.

Palavras-chave: ácidos graxos, índice de aterogenicidade, índice de trombogenicidade, *Oreochromis niloticus*.

Introduction

In 2013, Brazil produced 476,512 tons of fish by aquaculture. Continental aquaculture accounted for 82.37% (392,492 tons) and marine aquaculture was responsible for 17.63% (84,020 tons) of the production. The Northeast region was the largest producer of fish (140,748 tons), followed by the South region (107,448 tons). The continental aquaculture in Brazilis essentially represented by fish farming (Ministério da Pesca e Aquicultura [MPA], 2015).

The Food and Agriculture Organization of the United Nations (FAO) estimates that the Brazilian fish production may achieve an increase of 104% in fishing and aquaculture by 2025 (Food and Agriculture Organization [FAO], 2016).

There is a concern to increase the fishery production, mainly through aquaculture activity, as an alternative to provide healthy food. It is also

necessary to provide a subsidy for fishing communities to improve the fish products since 28% of the global fish production is used to prepare feed, or is considered as residues, which are discarded in the environment. Currently, about 50% of the biomass originated from fish processing in Brazil is discarded, without any type of reuse (Stevanato et al., 2007).

Studies on these residues are relevant since tilapia has an important significance in the national fishery, and because they make possible the use of residues generated by this activity, besides adding value to byproducts. These studies also aim to improve the fish products intake, due to their nutritional characteristics, especially regarding the fatty acids considered essential to the diet, responsible for many health benefits. Meal fatty acids can reduce the risk of coronary and cardiovascular diseases (Lorgeril et al., 1994; Singh, Niaz, Sharma, Kumar, & Rastogi, 1997); chronic neurodegenerative diseases (Youdim, Martin, & Joseph, 2000) such as Alzheimer's (Tully et al., 2003) and several types of cancer (Connolly, Coleman, & Rose, 1997; Rose, & Connolly, 1999).

This study aimed to determine the fatty acid composition and nutritional quality of total lipids in the adipose tissue from the orbital cavity of Nile tilapia (*Oreochromis niloticus*) from continental aquaculture in the State of Paraíba, Brazil.

Material and methods

Raw material

Nile tilapia raised in an intensive system was used as raw material for this study. Fish were caught in six different fish farms in the State of Paraíba, Brazil. The slaughtering process was carried out by asphyxia in ice. The tilapias were washed, and the adipose tissue from the orbital cavity was taken, frozen and subjected to lyophilization (L101–Liotop Lyophilizer).Samples were stored at -18ºC until the analysis.

Sampling of the feed used by fish farmers

The sampling of the feed used by fish farmers was carried out, by chance, simultaneously with the fish sampling.

Extraction of Total Lipids

Total lipid extraction was carried out according to Bligh and Dyer (1959). The total lipids were stored in amber bottles, under N_2atmosphere, identified and stored in a freezer at -18ºC until the analyses.

Fatty Acid Methyl Esters

The preparation of fatty acid methyl esters was made according to the method proposed by Joseph and Ackman (1992), by using BF_3/methanol. All the stages of the process were carried out under N_2atmosphere.

Fatty acid analysis

The fatty acid methyl esters were separated using a Gas chromatograph Varian 3380, equipped with flame ionization and fused-silica capillary column CP - 7420 (Select FAME) (100 m in length, 0.25 mm in internal diameter and 0.25 μm of cyanopropyl). The flux of H_2 (mobile gas) was 1.0 mL min^{-1}, with 30 mL min^{-1} N_2 (make up); and 300 mL min^{-1} synthetic air, for the detector flame. The volume injected was 1.0 μL, by using 1:80 split, and the injector and detector temperatures were 220 and 240ºC, respectively. The column temperature was 165ºC for 18 min. and increased to 235ºC at a rate of 4ºC $min.^{-1}$, which was kept for 24.5 min. Fatty acids were identified by comparison of retention times with Sigma standard (USA) and spiking coelution of standards together with the sample, and the ECL values were calculated from previously corrected retention time of the samples, which were compared with values available in the literature (Stransky, Jursik, & Vitek, 1997; Thompson, 1997). The concentrations were determined through the integration of peak areas using the Software Varian Workstation Star, version 5.0, and the results were expressed as percentages of thetotal lipid relative area.

Nutritional Quality Indices of Lipids (NQI)

The nutritional quality of the lipid fraction was determined in fatty acids by using the composition data from three indices:

Atherogenicity Index (AI) = [(C12:0 + 4xC14:0+C16:0)] / (ΣMUFA+ Σn-6+Σn-3);

Thrombogenicity Index (TI) = (C14:0+C16:0+C18:0) / [(0.5xΣMUFA)+(0.5xΣn-6) + (3xΣn-3) + (Σn-3/n-6)];

MUFA = monounsaturated fatty acids.

Ratio between Hypocholesterolemic / Hypercholesterolemic Fatty Acids (H/H) = (C18:1n-9+C18:2n-6+C20:4n-6+C18:3n-3+C20:5n-3+C22:5n-3+C22:6n-6) /(C14:0+C16:0).

The a therogenicity and thrombogenicity indices were calculated according to Ulbricht and Southgate (1991), and the ratio between Hypocholesterolemic / Hypercholesterolemic fatty acids according to Santos-Silva, Bessa and Santos-Silva (2002).

Statistical analysis

Data were analyzed by analysis of variance complemented by the Tukey test at 5% significance level using the SAS system, Licensed by the Federal University of Paraiba (Statistical Analisys System [SAS], 2004).

Results and discussion

Fatty acid composition in the adipose tissue from the orbital cavity

The total lipid fatty acid composition detected in the orbital cavity adipose tissue in Nile tilapia is shown in Table 1. Twenty-six components were detected in the total lipids of adipose tissue from the orbital cavity. Oleic (18:1n-9), palmitic (16:0), linolenic (LA, 18:2n-6), stearic (18:0) and palmitoleic acids (16:1n-7), in decreasing order, were the most abundant fatty acids detected.

Stevanato et al. (2008) identified 31 fatty acids in the head of fresh tilapia. The authors stated that there was a predominance of the following fatty acids: palmitic acid (16:0), with values varying from 22.73 to 25.27%; oleic acid (18:1n-9) ranging from 35.56 to 33.60%; and linoleic acid (18:2n-6), ranging from 11.58 to 11.69%.

A high content of palmitic fatty acid (16:0), among the group of saturated fatty acids, was found in the adipose tissue from the orbital cavity, with an average percentage of 24.31% (Table 1). Similar results were found in tucunaré (*Cichlaocelaris*) by Inhamuns, Franco and Batista (2009); mapará (*Hypophthalmus*sp.) by Inhamuns and Franco (2008); tambaqui (*Colossoma Macropomum*) by Almeida, Visentainer and Franco (2008); and matrinxã (*Bryconcephalus*) by Almeida and Franco (2007).

The fatty acids considered essential and belonging to the omega 3 family have shown values for α-linolenic (1.12 to 1.87), eicosapentaenoic acid (0.76 to 2.19), and docosahexaenoic acid (0.32 to 0.63). Several authors confirmed the presence of those essential fatty acids in residues of tilapia (Cengiz, Kan, Kizmaz, Bashan, & Yanar, 2012; Stevanato et al., 2008; Navarro et al., 2012; Tonial, Matsushita, Furuya, Souza, & Visentainer, 2012).

Table 1. Total lipid fatty acid composition (%) in adipose tissue from the orbital cavity of Nile tilapia.

	Fish Farm					
Fatty acid	I	II	III	IV	V	VI
14:0	2.58±0,06^{c}	2.94±0.02^{abc}	2.82±0.01^{bc}	3.34±0.08^{a}	3.16±0.07^{ab}	3.07±0.16^{ab}
14:1n-9	0.17±0.00^{b}	0.42±0.00^{a}	0.17±0.01^{b}	0.28±0.05^{b}	0.20±0.02^{b}	0.17±0.00^{b}
14:1n-7	0.13±0.00^{b}	0.16±0.01^{ab}	0.16±0.00a^{b}	0.20±0.03^{a}	0.19±0.00^{a}	0.16±0.01^{ab}
15:0	0.26±0,02^{b}	0.57±0.01^{a}	0.24±0.00^{b}	0.29±0.01^{b}	0.30±0.01^{b}	0.28±0.02^{b}
16:0	22.56±0.39^{b}	24.82±0.34^{ab}	24.30±0.05^{ab}	25.89±0.30^{a}	24.20±0.48^{ab}	24.08±1.2^{ab}
16:1n-9	0.67±0,01^{b}	0.85±0.01^{a}	0.62±0.01^{b}	0.67±0.01^{b}	0.69±0.02^{b}	0.67±0.04^{b}
16:1n-7	4.56±0.06^{b}	6.13±0.02^{a}	5.01±0.02^{bc}	5.74±0.08^{ab}	5.58±0.11^{ab}	5.12±0.3^{b}
17:0	0.645±0.01^{b}	1.19±0.02^{a}	0.51±0.02^{b}	0.59±0.01^{ab}	0.55±0.01^{b}	0.57±0.02^{bc}
17:1n-9	0.31±0.00^{b}	0.43±0.01^{a}	0.21±0.01^{c}	0.31±0.00^{b}	0.25±0.00^{c}	0.23±0.02^{c}
18:0	5.61±0.13^{b}	0.75±0.00^{d}	6.72±0.03^{a}	0.30±0.00^{d}	0.70±0.00^{d}	3.47±0.14^{b}
18:1n-9	29.59±0.44^{b}	29.62±0.27^{b}	33.08±0.22^{a}	34.22±0.06^{a}	33.53±0.52^{a}	29.35±0.20^{b}
18:1n-7	3.49±0.07^{b}	4.29±0.00^{a}	3.73±0.04^{ab}	4.16±0.17^{a}	3.89±0.08^{ab}	3.84±0.2^{ab}
18:2n-6	21.46±1.06^{a}	20.74±0.76^{a}	16.17±0.47^{a}	17.36±0.75^{a}	19.99±1.79^{a}	18.92±2.62^{a}
18:3n-6	1.42±0.14^{a}	1.06±0.02^{a}	0.79±0.00a	0.91±0.05^{a}	0.85±0.02^{a}	0.82±0.06^{a}
18:3n-3	1.25±0.02^{a}	1.87±0.05^{a}	1.14±0.01^{b}	1.13±0.02^{b}	1.13±0.02^{b}	1.12±0.06^{b}
20:0	0.30±0.01^{b}	0.44±0.01^{a}	0.30±0.02^{b}	0.32±0.02^{b}	0.27±0.01^{b}	0.27±0.02^{b}
20:1n-9	0.18±0.00^{a}	0.20±0.01^{a}	0.10±0.01^{b}	0.95±0.01^{b}	0.10±0.00^{b}	0.10±0.00^{b}
21:0	0.71±0.02^{a}	0.99±0.01^{a}	0.76±0.01^{a}	0.89±0.00^{a}	0.77±0.01^{a}	0.81±0.14^{a}
20:3n-3	0.80±0.02^{a}	0.77±0.02^{a}	0.73±0.00^{a}	0.70±0.00^{a}	0.71±0.00^{a}	0.69±0.05^{a}
20:2n-6	0.91±0.02^{a}	0.79±0.03^{a}	0.83±0.01^{a}	0.60±0.01^{b}	0.85±0.01^{a}	0.92±0.06^{a}
20:4n-6	0.12±0.00^{a}	0.07±0.00^{b}	0.14±0.01^{a}	0.06±0.0^{b}	0.06±0.00^{b}	0.08±0.00^{b}
20:5n-3	1.01±0.09^{b}	0.45±0.08^{b}	0.76±0.06^{b}	1.08±0.17^{b}	1.40±0.31^{ab}	2.19±024^{a}
22:4n-6	0.54±0.02^{a}	0.05±0.01^{b}	0.43±0.12^{a}	0.41±0.07^{a}	0.50±0.02^{a}	0.525±0.04^{a}
24:0	0.41±0.01^{a}	0.47±0.02^{a}	0.36±0.00^{a}	0.40±0.00^{a}	0.42±0.05^{a}	0.41±0.04^{a}
24:1n-9	0.03±0.00^{a}	0.06±0.00^{a}	0.03±0.01^{a}	0.03±0.00^{a}	0.04±0.01^{a}	0.03±0.00^{a}
22:6n-3	0.32±0.01^{c}	0.63±0.03^{a}	0.39±0.00^{c}	0.51±0.01^{b}	0.37±0.01^{c}	0.37±0.03^{c}
SFA	33.07±0.61^{b}	31.48±0.38^{ab}	35.99±0.06^{a}	31.73±0.42^{ab}	29.72±0.53^{b}	32.80±1.73^{ab}
MUFA	39.14±0.59^{b}	42.13±0.32^{ab}	43.09±0.22^{ab}	45.69±0.40^{a}	44.45±0.72^{ab}	41.80±2.5^{ab}
LC-PUFA	27.80±1.20^{a}	26.39±0.70^{ab}	20.92±0.15^{c}	22.58±0.81^{bc}	25.85±1.24^{abc}	25.40±0.78^{abc}
ΣFAn-6	24.44±1.16^{a}	22.70±0.71^{a}	18.22±0.21^{a}	19.18±0.47^{a}	22.24±1.77^{a}	21.25±2.46^{a}
ΣFAn-3	3.37±0.03^{a}	3.70±0.01^{a}	2.71±0.37^{a}	3.41±0.35^{a}	3.60±0.54^{a}	4.16±1.69^{a}
LC-PUFA/SFA	0.84±0.05^{a}	0.84±0.03^{a}	0.58±0.00^{b}	0.72±0.03^{ab}	0.87±0.06^{a}	0.78±0.02^{ab}
n-6/n-3	7.27±0.27^{a}	6.14±0.21^{a}	6.87±1.0^{a}	5.68±0.44^{a}	6.40±1.45^{a}	6.41±3.19^{a}

SFA: saturatedfattyacids; MUFA: monounsaturatedfattyacids; LC-PUFA: polyunsaturatedfattyacids (unsaturation ≥ 2); n-6: omega-6 fattyacids; n-3: omega-3 fattyacids; LC-PUFA/SFA: polyunsaturated/saturatedfattyacidratio; n-6/n-3: omega-6/omega-3 fattyacidratio. Different letters in the same row indicate significant difference ($p < 0.05$) according to Tukey's test.

The docosahexaenoic acid (DHA) is a very important fatty acid responsible for the physical properties of the brain membranes, the features of their receptors, the cellular interactions and the enzymatic activity (Yehuda, Rabinovitz, Carasso, & Mostofsky, 2002).

Among the polyunsaturated fatty acids, there was a high content of linoleic acid (18:2n-6) in all the samples. Almeida et al. (2008) and Almeida and Franco (2007) found values of 9.57 and 9.35% for 18:2n-6 in the orbitalcavity of tambaqui and matrinxã, respectively, in the Brazilian Amazon. It is interesting to note that the values of 18:2n-6 in the feed were between 32.99 and 37.57%. The diets provided to fish can affect the lipid content, especially the fatty acid composition (Om et al., 2001).

High proportions of n-6 polyunsaturated fatty acids characterize the fatty acid composition of freshwater fish, especially linoleic and arachidonic acids (Steffens, 1997).

The arachidonic acid (AA) is related to the development of brain and retina during the period of gestation and the first years of human life. The values for arachidonic acid (AA, 20:4n-6) obtained in this research were considered low. The values varied from0.06 to 0.14% among fish from different fish farms.

AGMI presented high proportions of the fatty acid groups, characterized the total lipids in the orbital cavity. According to Ewin (1997),from the nutritional point of view, the ingestion of saturated fatty acids increases the content of serum cholesterol in humans; however, the total cholesterol content in plasma decreases when the ingestion of saturated fatty acids is replaced with monounsaturated fatty acids.

The relations or proportions between fatty acids have been studied to assess and identify the risk factor of food regarding the increase of cholesterol level in human blood. The biological effect of essential fatty acids depends on the ratio between LC-PUFA/SFA. This relationship helps to determine the risk factors in food (Marques et al., 2007).

The n-6 and n-3 fatty acids influenced the metabolism of eicosanoids, the gene expression, and the inter-cellular communication. The composition of LC-PUFA in the cellular membranes considerably depends on the amount ingested. In this sense, it is important to consider the recommendations of the appropriate amount of these fatty acids for the daily intake, as well as the balance of the n-6/n-3ratio, which is essential for the human metabolism, preventing cardiovascular and chronic degenerative diseases, leading to a better mental health (Simopoulus, 2000).

Many countries, such as Germany, Canada, Japan, and the USA, have already made recommendations on the omega 6/omega 3 ratio for human health. In Canada, the recommended proportion of n-6/n-3 should be between 4.0 and 10, according to the Scientific Review Committee (1990).

Fatty acid composition of feed

The fatty acids composition and the sum of SFA, MUFA, LC-PUFA, fatty acids n-6 and n-3, and the LC-PUFA/SFA and n-6/n-3ratiosin the feed are listed in Table 2.

Twenty-six components were detected in the total lipids of feed. In decreasing order, linolenic acid (LA, 18:2n-6), oleic acid (18:1n-9), palmitic acid (16:0), alpha linoleic acid (18:3n-3), vaccenic acid (18:1n-7), palmitoleic acid (16:1n-7) and myristic acid (14:0) were the most abundant fatty acids detected.

Lipids are fundamental to the health, survival, and success of fish populations. The functions of these molecules in fish growth are well defined, namely: energetic, structural, hormonal, precursors of eicosanoids and among others (Haliloglu, Bayır, Sirkecioğlu, Aras, & Atamanalp, 2003). Among lipids, polyunsaturated fatty acids are required for normal growth and development, mainly by maintaining the structural and functional integrity of membranes (Sargent, Bell, McEvoy, Tocher, & Estevez, 1999).

High proportions of LC-PUFA with values of 36.85 and 41.459% respectively for fish from farm II and for fish from farm V characterized the total lipids in the feed. The linolenic acid was the main responsible for the high content of LC-PUFA (Table 2).

Diets given to fish directly affect the muscle composition, especially regarding the lipid content and the composition of fatty acids (Om et al., 2001). The importance of lipids in diets for aquatic organisms is associated with the increase of palatability, the improvement of the muscle tissue texture and the fatty acids profile (Martino & Portz, 2006; Martino & Takahashi, 2001). Rainuzzo, Reitan, and Olsen (1997) emphasized the importance of knowing type and amount of lipid in the diet of animals because of their influence on the quality and quantity of PUFA in the tissues.

Table 2. Total lipid fatty acid composition (%) in feed of Nile tilapia.

	Fish Farm					
Fatty acid	I	II	III	IV	V	VI
14:0	1.15±0.02^{bc}	1.43±0.02^{a}	1.19±0.04^{b}	1.065±0.02^{cd}	1.25±0.01^{b}	1.02±0.03^{d}
14:1n-9	0.15±0.0^{b}	0.29±0.03^{a}	0.15±0.00^{b}	0.135±0.01^{b}	0.18±0.00^{b}	0.14±0.01^{b}
14:1n-7	0.10±0.0^{d}	0.15±0.0^{a}	0.13±0.00^{b}	0.12±0.0b^{c}	0.12±0.00^{bc}	0.11±0.00^{cd}
15:0	0.25±0.01^{b}	0.33±0.0^{a}	0.20±0.00^{c}	0.20±0.01^{c}	0.30±0.00^{a}	0.20±0.00^{c}
16:0	18.82±0.15^{ab}	19.11±0.27^{a}	18.20±0.36^{ab}	17.90±0.07^{b}	18.85±0.04^{ab}	17.79±0.05^{b}
16:1n-9	0.30±0.01^{a}	0.22±0.02^{a}	0.22±0.03^{a}	0.14±0.01^{a}	0.20±0.08^{a}	0.13±0.01^{a}
16:1n-7	1.64±0.01^{a}	1.41±0.03^{bc}	1.47±0.04^{b}	1.26±0.02^{d}	1.04±0.04^{c}	1.26±0.01^{cd}
17:0	0.70±0.01^{b}	0.77±0.01^{a}	0.49±0.01^{c}	0.49±0.01^{c}	2.67±0.01^{b}	0.49±0.00^{c}
17:1n-9	0.14±0.0^{b}	0.19±0.01^{a}	0.16±0.01^{b}	0.15±0.00^{b}	0.18±0.00^{a}	0.15±0.00^{b}
18:0	9.06±0.07^{bc}	10.55±0.2^{a}	8.40±0.12^{d}	8.49±0.01^{cd}	9.70±0.04^{b}	8.55±0.14^{cd}
18:1n-9	25.81±0.07^{a}	25.86±0.51^{a}	27.29±0.53^{a}	28.54±0.27^{a}	23.10±0.08^{a}	22.93±5.82^{a}
18:1n-7	2.08±0.03^{a}	1.96±0.0^{a}	2.22±0.05^{a}	2.42±0.25^{a}	1.96±0.08^{a}	2.37±0.14^{a}
18:2n-6	35.20±0.55^{ab}	32.99±0.89^{b}	35.74±1.13^{ab}	34.81±0.22^{ab}	37.57±0.20^{a}	34.74±0.13^{ab}
18:3n-6	0.09±0.01^{a}	0.05±0.01^{a}	0.09±0.03^{a}	0.04±0.01^{a}	0.04±0.01^{a}	0.04±0.00^{a}
18:3n-3	2.36±0.02^{c}	2.11±0.04^{d}	2.40±0.04^{c}	2.63±0.0^{c}	3.00±0.03^{a}	2.63±0.02^{c}
20:0	0.65±0.00^{a}	0.65±0.02^{a}	0.50±0.01^{b}	0.52±0.0^{b}	0.50±0.02^{b}	0.51±0.01^{b}
20:1n-9	0.03±0.01	0.02±0.00^{a}	0.02±0.01^{a}	0.02±0.0^{a}	0.34±0.03^{a}	0.20±0.19^{a}
21:0	0.13±0.01^{a}	0.13±0.01^{a}	0.13±0.02^{a}	0.07±0.01^{a}	0.75±0.00^{a}	0.11±0.02^{a}
20:3n-3	0.09±0.0^{a}	0.05±0.01^{c}	0.10±0.01^{a}	0.75±0.0^{ab}	0.05±0.00^{bc}	0.75±0.00^{ab}
20:2n-6	0.39±0.0^{a}	0.23±0.01^{b}	0.22±0.01^{bc}	0.15±0.0^{c}	0.21±0.02^{bc}	0.17±0.02^{bc}
20:4n-6	0.1±0.0^{b}	0.85±0.00^{b}	0.09±0.01^{b}	0.06±0.0^{c}	0.16±0.00^{a}	0.60±0.00^{c}
20:5n-3	0.37±0.18^{b}	1.05±0.15^{a}	0.27±0.05^{a}	0.09±0.03^{b}	0.12±0.07^{b}	0.08±0.02^{b}
22:4n-6	0.18±0.00^{a}	0.19±0.01^{a}	0.14±0.0^{c}	0.17±0.01^{abc}	0.15±0.00^{bc}	0.17±0.00^{ab}
24:0	0.02±0.00^{a}	0.02±0.01^{a}	0.02±0.0^{a}	0.19±0.08^{a}	0.01±0.00^{a}	0.01±0.00^{a}
24:1n-9	0.09±0.01^{abc}	0.11±0.0^{ab}	0.09±0.01^{bc}	0.07±0.00^{c}	0.12±0.00^{a}	0.07±0.0^{c}
22:6n-3	0.14±0.00^{ab}	0.11±0.0^{c}	0.12±0.00^{bc}	0.07±0.00^{d}	0.16±0.00^{a}	0.07±0.01^{c}
SFA	30.77±0.25^{bc}	32.97±0.47^{a}	29.11±0.55^{cd}	29.08±0.25^{cd}	31.34±0.0^{ab}	28.66±0.06^{d}
MUFA	30.33±0.11^{b}	30.19±0.5^{b}	31.73±0.60^{ab}	38.84±0.0^{a}	27.22±0.14^{c}	33.30±0.10^{a}
LC-PUFA	38.91±0.37^{ab}	36.85±0.97^{b}	39.17±1.15^{ab}	38.09±0.24^{ab}	41.45±0.14^{a}	38.04±0.16^{ab}
ΣFAn-6	35.96±0.55^{ab}	33.54±0.87^{b}	36.29±1.15^{ab}	35.22±0.21^{ab}	38.12±0.18^{a}	35.19±0.15^{ab}
ΣFAn-3	2.95±0.19^{a}	3.31±0.10^{a}	2.88±0.00^{a}	2.87±0.03^{a}	3.33±0.04^{a}	2.85±0.02^{a}
LC-PUFA/SFA	1.27±0.03^{ab}	1.12±0.04^{b}	1.35±0.06^{a}	1.31±0.02^{ab}	1.33±0.01^{a}	1.33±0.01^{a}
n-6/n-3	12.28±0.96^{ab}	10.14±0.05^{b}	12.60±0.40^{a}	12.29±0.06^{ab}	11.45±0.19^{ab}	12.33±0.0^{ab}

SFA: saturatedfattyacids; MUFA: monounsaturatedfattyacids; LC-PUFA: polyunsaturatedfattyacids (unsaturation ≥ 2); n-6:omega-6 fattyacids; n-3: omega-3 fattyacids; LC-PUFA/SFA: polyunsaturated/saturatedfattyacidratio; n-6/n-3: omega-6/omega-3 fattyacidratio.Significant difference at a level of 5% is designated by 'a' and 'b', (Tukey's test); the same letters in the same row indicate no significant difference according to Tukey's test.

Lipid Nutritional Quality

The thrombogenicity index and atherogenicity index were proposed by Ulbricht and Southgate (1991) with the aim of considering not only the family of fatty acids but also their biological effect. Thus, TI relates the content of saturated fatty acids 14:0 16:0 and 18:0 (prothrombotic) with the content of monounsaturated and polyunsaturated fatty acids n-3 and n-6 (antithrombotic), indicating the contribution the food product may have in the formation of clots in the blood vessels (Senso, Suarez, Ruiz-Cara, & Garcia-Gallego, 2007). On the other hand, AI is based on the information about the effect the several fatty acids have on the plasmatic cholesterol, specifically in the formation of LDL and HDL.

The values of the atherogenicity index (AI), thrombogenicity index (TI) and theratio between hypocholesterolemic and hypercholesterolemic fatty acids (H/H) are shown in Table 3.

Lipid nutritional quality indicesfor the adipose tissue from the orbital cavity of tilapia ranged from 0.49 to 0.58 for AI; 0.55 and 0.74 for TI. The ratio between hypocholesterolemic and hypercholesterolemic fatty acids presented values above 2 for fish farms I and VI (Table 3).

Table 3. Total lipid nutritional quality indexes in adipose tissue from the orbital cavity of Nile tilapia.

Fish	Indices and Ratio		
Farms	AI	TI	H/H
I	0.49±0.014^{b}	0.63±0.020^{b}	2.18±0.072^{a}
II	0.54±0.006^{ab}	0.56±0.010^{bc}	1.92±0.039^{a}
III	0.56±0.002^{ab}	0.74±0.004^{a}	1.92±0,028^{a}
IV	0.58±0.013^{a}	0.61±0.016^{bc}	1.870±0.053^{a}
V	0.53±0.015^{ab}	0.55±0.015^{c}	2.085±0,075^{a}
VI	0.54±0.013^{ab}	0.61±0.001^{bc}	1.945±0.186^{a}

AI: Atherogenicity Index; TI: Thrombogenicity Index; H/H: ratio between hypocholesterolemic and hypercholesterolemic fatty acids. Significant difference at a level of 5% is designated by 'a' and 'b', (Tukey's test); the same letters in the same row indicate no significant difference according to Tukey's test.

The atherogenicity index results found by Tonial et al. (2011), in fillets of tilapiafed diets supplemented with soybean oil, varied from 0.67 to 0.49, from 0 to 90 days, respectively. Senso et al. (2007) reported values from 0.21 to 0.29 for AI in *Sparusarata*. These studies presentedlower values, which can be justified by the factthatthe fish tissue (fillet) has less polyunsaturated fatty acids compared to the fish eye, as well as by the interference of other factors, such as diet.

There are no recommended values for the AI and TI. It is considered that low values are related to more favorable fatty acids, in terms of health. Therefore, low values of these indices represent a

beneficial effect on human health since they help to prevent the occurrence of coronary diseases (Turan, Sönmez, & Kaya, 2007).

Values between 1.87 and 2.18were found for the H/H ratio in the adipose tissue from the orbital cavity analyzed. These values were higher than those observed by Ramos, Ramos, Hiane, and Souza (2008), in freshwater fish raised in Pantanal, State of Mato Grosso, Brazil, who verified values ranging from 1.49 to 1.84 in themuscleof *Salminus maxillosus* and *Pseudoplatystoma coruscans*, respectively.

According to the literature, the higher the H/H index, the more suitable is the fat for the human diet. It is worth emphasizing that, for meat products, the ideal value should be close to 2 (Bentes, Souza, Mendonça, & Simões, 2009). The H/H ratio in the adipose tissue from the orbital cavity of fish was strongly influenced by the content of oleic acid.

Conclusion

The LC-PUFA/SFA ratio of the adipose tissue of the orbital cavity was considered satisfactory for the humandiet because it presented values within the recommended levels, which are above 0.45.The adipose tissue of the orbital cavity of fish presented essential fatty acids, such as linoleic acid and alpha-linolenic acid, in addition to fatty acids of important nutritional value such as arachidonic acid, eicosapentaenoic acid, and docosahexaenoic acid. Regarding the lipid nutritional quality, through atherogenicity and thrombogenicity indexes and the H/Hratio, the tilapia residue analyzed in the present study can be recommended for human consumption or to elaborate products for animal feeding.

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