Fatty acids and nutrients in the flour made from tilapia (*Oreochromis niloticus*) heads

Ácidos graxos e nutrientes em farinha de cabeças de tilápia (Oreochromis niloticus)

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Abstract

The objective of this work was to analyze the fatty acid composition and nutrient potential of flour made from tilapia heads, which are normally discarded during the filleting operation. Significant differences were found between the proximate composition (moisture, ash, protein and total lipids) of the in natura tilapia and the flour, due to the drying process. The predominant fatty acids in the heads (in natura and in the flour) were palmitic acid (1,999 mg.100 g^{-1} and 7,699 mg.100 g^{-1}, respectively), oleic acid (3,128 mg.100 g^{-1} and 11,447 mg.100 g^{-1}, respectively), and linoleic acid (1,018 mg.100 g^{-1} and 3,784 mg.100 g^{-1}, respectively). The results lead us to conclude that tilapia head flour offers high levels of protein (38.41%), total lipids (35.46%), and ash (minerals) (19.38%). The content of omega-3 (731 mg.100 g^{-1}) were proved to be satisfactory. Also, n-6/n-3 ratio was 6.15 and PUFA/SFA ratio was 0.47, which are in agreement with the recommended levels. Thus, tilapia heads can be used as a low-cost raw material for food fit for human consumption.

Keywords: *tilapia; heads; flour; fatty acids; nutrients.*

Resumo

O objetivo deste trabalho foi avaliar a composição em ácidos graxos e o potencial em nutrientes em cabeças de tilápias in natura processadas na forma de farinha. As cabeças de tilápia normalmente são resíduos não aproveitados e descartados na operação de filetagem pelas indústrias e pesqueiros. Diferenças significativas foram encontradas na composição centesimal (umidade, cinza, proteína e lipídios totais) entre as cabeças de tilápia in natura e a farinha, provavelmente devido ao processo de secagem. Os ácidos graxos predominantes nas cabeças (in natura e na farinha) foram os ácidos: palmítico (1.999 mg.100 g^{-1} e 7.699 mg.100 g^{-1}, respectivamente), oléico (3.128 mg.100 g^{-1} e 11.447 mg.100 g^{-1}, respectivamente) e linoléico (1.018 mg.100 g^{-1} e 3.784 mg.100 g^{-1}, respectivamente). Os resultados da farinha da cabeça apresentaram elevados teores de proteína (38,41%), de lipídios totais (35,46%) e de cinza (19,38%). A concentração de ácidos ômega-3 (731 mg.100 g^{-1}) indica que a farinha é uma boa fonte destes ácidos e as razões n-6/n-3 de 6,15 e AGPI/AGS de 0,47 estão de acordo com os níveis recomendados para uma alimentação saudável. Desta forma, as cabeças de tilápia podem ser utilizadas como um alimento nutritivo e de baixo custo para o consumo humano.

Palavras-chave: *tilápia; cabeças; farinha; ácidos graxos; nutrientes.*

1 Introduction

The Nile tilapia (*Orechromis niloticus*) is one of the most cultivated fresh-water fish in Brazil and worldwide (JORY; ALCESTE; CABRERA, 2000). From the capture to the end processing of this fish, approximately 28% of the total catch is wasted. Sometimes the waste is used to produce processed animal feed, but most often it is discarded, contributing to increase environmental pollution (FAO, 2000). By fish waste, we mean small or dark-meat fish, fatty tissue, and parts such as the head, scales, spinal column, skeleton, liver, skin and viscera (OETTERER, 2003).

It should be considered that fish tissue presents high nutritional value and therefore is a particularly recommended dietary component (ZMIJEWSKI et al., 2006). Protein from fish tissue is characterized by a desirable amino acid composition. The tissue is also rich in vitamins A, D and the B group. In addition, fish are a good source of micro and macro-elements such as calcium, phosphorus, selenium and manganese (KOLAKOWSKA; KOLAKOWSKI, 2000). Muscle (JUSTI et al., 2003; VISENTAINER et al., 2005) and waste of fish, such as the head (MOREIRA et al., 2003), are the main source of very-long-chain (number of carbons ≥20) polyunsaturated fatty acids (n-3 VLC-PUFAs), which have beneficial and even therapeutic effects on human health (ACKMAN, 2000; GARCIA, 1998; KOLANOWSKI; SWIDERSKI; BERGER, 1999). Eicosapentaenoic (EPA, 20:5n-6) and docosahexaenoic (DHA, 22:6n-3) fatty acids have been the subject of innumerable studies in the past few decades, being important for their various benefits to human health, including lowering the risk of cardiovascular diseases (DYEBERG; BANG, 1979; FIRBANK et al., 2002; PENNY et al., 2002), anti-inflammatory and antithrombotic effects (SIMOPOULOS, 2002), reduction of blood cholesterol levels and cancer prevention (LEE; LIP, 2003).

Recommendations for the inclusion of n-3 fatty acids in the human diet in relation to n-6 fatty acids have been made

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in several countries and currently the suggested n-6/n-3 ratio values range from 2 to 5.1 (CHARDIGNY; BRETILLON; SEBÉDIO, 2001; SCHAEFER, 2002; SIMOPOULOS; LEAF; SALEM, 1999).

In many countries of the world, the huge quantities of fish waste produced are often discarded into the environment and become a source of pollution. In literature, there are practically no studies on fish waste products and they are very seldom utilized for food. With these facts in mind, the aim of the present work is to evaluate the fatty acid composition and nutrient potential of tilapia heads, in natura and after processing in the form of flour, with the ultimate goal of its consumption by humans.

2 Materials and methods

2.1 Sampling

The tilapia heads (35 heads) were washed with filtered water, cleaned (dried) with paper towels and steam-cooked (pans on the stove) for 25 minutes. After cooking, the heads were ground in an endless-screw grinder, placed on trays and dried in an oven for 4 hours at 180 °C. Next, the flour was sieved using a 14-mesh stainless steel sieve. The steps shown in the flowchart in Figure 1 were followed for THF (Tilapia Head Flour) processing.

2.2 Analytical methods

Moisture and ash contents were determined gravimetrically by desiccation of the samples at 105 °C and by incineration in an oven at 600 °C, respectively. Crude protein was obtained by the Kjeldahl method (CUNNIFF, 1998), and total lipids were extracted from muscle tissue using the Bligh and Dyer method (BLIGH; DYER, 1959). Three replicates were used in all chemical analyses.

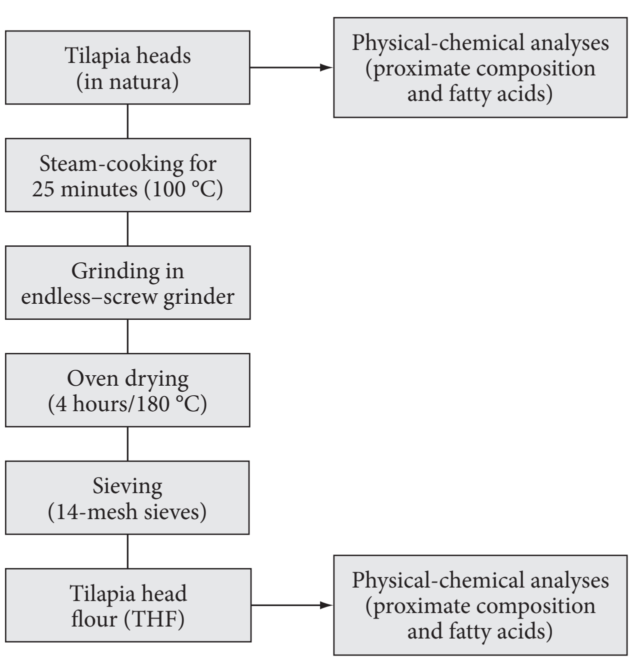

Figure 1. Flowchart for tilapia head flour (THF) production.

Fatty acid methyl esters (FAME) were prepared by methylation of the total lipids (TL), as described by Joseph and Ackman (1992). Fatty acid esters were separated in a gas chromatograph 14-A (Shimadzu, Japan) equipped with a fused silica capillary column CP-cyanopropyl (Select fame Varian - CP 7420) (100 m x 0.25 mm i.d. x 0.25 µm film) and flame ionization detector. The operation parameters were as follows: detector temperature, 240 °C; injection port temperature, 220 °C; column temperature, 165 °C for 18 minutes, programmed to increase at 4 °C/min to 235 °C, with a final holding time of 24 minutes. The gas flow rates used were 1.0 mL/min, carrier gas (H_2), 30 mL/min make-up gas (N_2), and 30 and 300 mL/min flame gases (H_2 and synthetic air, respectively). The sample splitting rate was 1:50 and samples (1 µL) were injected in triplicate. Peak areas were determined by Varian Star acquisition program. For the identification of the fatty acids, their retention times were compared to those of standard methyl esters (Sigma, St. Louis, MO, USA). Equivalent chain-length values (ECL) were used, according to Stransky, Jursik and Vitek (1997) and Thompson (1996). Data were calculated using the normalized peak area percentages of total fatty acid content and converted into mg.100 g^{-1} lipids using a conversion factor for fish according to Weihrauch et al. (1977).

2.3 Statistical analysis

The results were submitted to analysis of variance (ANOVA) and the Tukey test (5% probability) using the Statistica 5.0 software (STATSOFT, 1995).

3 Results and discussion

The average mass of ground in natura tilapia heads (total of 35 heads) was 5.54 kg. After cooking, grinding, drying and sieving, 1.99 kg were obtained, which corresponds to 35.9% of the initial mass and 10.8% in relation to the whole fish.

Analyzing the proximate composition (moisture, crude protein, ash and total lipids) of the in natura tilapia heads and of tilapia head flour (Table 1), it was possible to observe that there are statistically significant differences ($p < 0.05$) between the levels of moisture, crude protein, ash and total lipids, as the concentrations of the three latter increased due to the water removal during the drying process and due to the sieving process that preferentially retained material rich in protein. The amount of moisture found in in natura tilapia heads was 67.24% (Table 1) and decreased to 6.01% in the tilapia head flour. These values are in accordance to the Riispoa (1997), which requires whole dried fish moisture content to be lower than 12%.

Table 1. Proximate composition of in natura tilapia heads and tilapia head flour (THF).

Constituents	Moisture (%)	Crude protein b (%)	Ash (%)	Total lipids (%)
In natura	67.24 ± 0.20^a	16.48 ± 0.15^a	5.72 ± 0.04^a	9.56 ± 0.39^a
Flour	6.01 ± 0.09^b	38.41 ± 0.12^b	19.38 ± 0.14^b	35.46 ± 0.16^b

Each value is the average of five samples analyzed in triplicate with the respective standard deviations. The means followed by different letters in the same column are statistically different ($p < 0.05$) by the Tukey test. The protein content was determined by the Kjeldahl nitrogen determination method using 6.25 as conversion factor.

Crude protein (16.48%) and ash (5.72%) levels of in natura heads increased to 38.41 and 19.38% in tilapia head flour, respectively, due to water elimination. It should be stressed that part of the crude protein was retained in the sieving process. These values point to tilapia head flour as an important nutritional alternative, due to its high levels of proteins and minerals, as compared to other human foods.

Total lipids found in in natura heads was 9.56%, which is lower than that found by Moreira et al. (2003) for freshwater fish raised in captivity (piraputanga, matrinxã and piracanjuba), with average total lipids of 20.5%. The total lipid content of the flour (35.46%) is the highest among foods, making this flour a highly caloric product.

A total of 31 fatty acids were identified in the lipids of in natura heads and tilapia head flour (Table 2). The predominant fatty acids found were palmitic (PA, 16:0), oleic (OA, 18:1n-9), and linoleic (LA, 18:2n-6). These fatty acids were also the main fatty acids found in matrinxã, piraputanga and piracanjuba fillets by Moreira et al. (2001).

Arachidonic acid (AA, 20:4n-6), an important compound for child development, was found in quantities of 4 mg.100 g^{-1} in in natura tilapia heads and 16 mg.100 g^{-1} in tilapia head flour.

Among the fatty acids of greatest nutritional importance, the n-3 series stands out. Alpha-linolenic acid (ALA, 18:3n-3), a precursor of other n-3 fatty acids, was found in levels of 98 mg.100 g^{-1} and 316 mg.100 g^{-1} in in natura tilapia heads and in the flour, respectively. The percentages of the fatty acids EPA and DHA found in in natura heads and in the flour were 3 mg.100 g^{-1} and 10 mg.100 g^{-1}, and 48 mg.100 g^{-1} and 212 mg.100 g^{-1}, respectively. The values of DHA in the flour are in accordance to those obtained by others authors (MOREIRA et al., 2003).

There were statistically significant differences among the sums of PUFA, MUFA, SFA, n-6, n-3 or the PUFA/SFA and n-6-/n-3 ratios between the in natura heads and the flour (Table 2), because the total lipid content in the tilapia head flour is higher than the total lipid content in the in natura tilapia heads.

The values found for in natura head PUFA and SFA were 1,414 mg.100 g^{-1} and 2,982 mg.100 g^{-1}, respectively. According to the British Department of Health and Social Security (DHSS, 1986), PUFA/SFA ratios lower than 0.45 are associated with unhealthy products, especially for people who suffer from cardiovascular diseases. Based on this indicator, the value of 0.47 found for the PUFA/SFA ratio in in natura heads proves the flour to be a healthy food source. Moreover, the results show that processing in natura heads into flour has no effects on the PUFA/SFA ratio. PUFA/SFA values of 1.43 were found by Turon et al. (2005) for Nile perch heads, which is higher than the values in in natura tilapia heads and flour found in the present work (Table 2).

The n-6/n-3 fatty acid ratios for in natura heads and the flour were found to be 5.87 and 6.15, respectively, and showed no significant differences due to the drying process. The values found for n-6/n-3 in this experiment were greater than 4.0 and were in the range from 5 to 10, which was recommended by Simopoulos, Leaf and Salem (1999).

Table 2. Fatty acids (mg.100 g^{-1}) in in natura tilapia heads and in tilapia head flour (THF)[1].

Fatty acid	In natura	THF
14:0	241 ± 12[a]	829 ± 42[b]
14:1n-9	12.0 ± 5[a]	49 ± 6[b]
15:0	8.00 ± 1[a]	68 ± 6[b]
16:0	1,999 ± 43[a]	7,699 ± 35[b]
16:1n-9	60 ± 2[a]	238 ± 6[b]
16:1n-7	470 ± 7[a]	1,882 ± 10 1[b]
16:1n-5	14 ± 1[a]	49 ± 8[b]
17:0	31 ± 3[a]	111 ± 26[b]
17:1n-9	27 ± 6[a]	88 ± 29[b]
18:0	622 ± 34[a]	2,208 ± 26[b]
18:1n-9	3,128 ± 48[a]	1,1447 ± 401[b]
18:1n-7	253 ± 37[a]	757b ± 52[b]
18:1n-5	11 ± 3[a]	42a ± 3[b]
18:2n-6 (LA)	1,018 ± 22[a]	3,784 ± 114[b]
18:3n-6	78 ± 6[a]	271 ± 10[b]
18:3n-3 (ALA)	98 ± 2[a]	316 ± 10[b]
20:0	18 ± 3[a]	72 ± 6[b]
20:1n-9	152 ± 20[a]	571 ± 32[b]
21:0	27 ± 1[a]	114 ± 10[b]
20:2n-6	47 ± 4[a]	186 ± 16[b]
20:3n-6	55 ± 3[a]	215 ± 23[b]
20:3n-3	10 ± 1[a]	23b ± 6[b]
22:1n-9	94 ± 2[a]	398 ± 13[b]
22:2n-6	5 ± 1[a]	23 ± 2[b]
20:4n-6 (AA)	4 ± 1[a]	16 ± 2[b]
20:5n-3 (EPA)	3 ± 1[a]	10 ± 4[b]
22:0	20 ± 1[a]	75 ± 10[b]
24:0	4 ± 1[a]	13 ± 1[b]
24:1n-9	52 ± 6[a]	221 ± 22[b]
22:4n-3	47 ± 2[a]	192 ± 22[b]
22:6n-3 (DHA)	48 ± 2[a]	212 ± 19[b]
Not identified	115 ± 8[a]	440 ± 39[b]
PUFA	1,414 ± 60[a]	5,226 ± 133[b]
MUFA	4,274 ± 69[a]	15,743 ± 427[b]
SFA	2,982 ± 60[a]	11,191 ± 68[b]
n-6	1,208 ± 29[a]	4,495 ± 120[b]
n-3	206 ± 9[a]	731 ± 55[b]
PUFA/SFA	0.47 ± 0.01	0.47 ± 0.01
n-6/n-3	5.87 ± 1.22	6.15 ± 0.50

[1]Each value is the average of five samples analyzed in triplicate with the respective standard deviations (n = 15). Data were calculated using the conversion factor for fish according to Weihrauch et al., 1975. The means followedby different letters in the same line are statistically different ($p < 0.05$)by the Tukey test. Acronyms: PUFA - Polyunsaturated Fatty Acids; MUFA - Monounsaturated Fatty Acids; SFA - Saturated Fatty Acids; n-6 and n-3 fatty acids.

4 Conclusion

The results found lead us to conclude that processed tilapia heads in the form of flour present a high nutritive value in relation to their protein, total lipids and ash (minerals) contents. The omega-3 fatty acid content is proved to be satisfactory by the PUFA/SFA and the n-6/n-3 ratios and within the recommended levels. We thus conclude that tilapia heads can be used for human consumption, as a nutritive and low-cost food, adding value to a waste product that would otherwise contribute to environmental pollution.

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