THE INFLUENCE OF THERMAL FRYING TREATMENTS ON THE NUTRITIONAL AND HEALTH PROPERTIES OF FISH MEAT

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Abstract

Fish meat is a distinct food in human diets, as it is highly digestible and has the ability to provide a wide range of micronutrients, vitamins, amino acids and fatty acids in considerable quantities.

In the last period of time, especially, in accordance with the studies on the specific nutritional factors of fish meat, the interest in the consumption of this aquatic product has increased, due to the determination and evaluation of the high content of PUFA omega-3 fatty acids, with a significant role for health, in especially eicosapentaenoic acid (20:5n-3, EPA) and docosahexaenoic acid (22:6n-3, DHA). Long-chain n-3 polyunsaturated fatty acids, including α-linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are particularly important for human health, having been certified to protect the human body against cardiovascular disease, accelerated neurodegeneration and to reduce the inflammatory syndrome.

In addition to playing an important role in cardiovascular and inflammatory diseases, essential fatty acids are vital in the development of neurons in fetuses and infants, and ensure the control of glycolytic metabolism.

However, fish meat and fish meat products are by no means risk-free. Thus, a careful evaluation of the provenance and existing trophic chains in the geographical areas of origin of the fish is required, as well as the analysis of the impact generated by the meat preservation methods and procedures.

Frying, for example, is one of the complex processes that can significantly change the nutritional composition of the fried food product. Among the processing techniques, food frying has gained more and more acceptance, all over the world, but a whole series of research they highlight multiple disadvantages, both from a nutritional and physiological point of view.

During frying, the fat breaks down and many reactions occur that result in numerous structural transformations recorded by the fatty acids, namely the formation of trans fatty acids.

Conclusively, following the analysis of the obtained experimental data, it is highlighted that the proportion of saturated fatty acids (SFA) in raw fish muscle was lower (26.01%) compared to fried fish muscle (29.05%), the ratio n-3/ n-6 changed after frying (0.44, in raw meat and 0.29 in fried meat), the Atherogenicity Index varied between 0.38, in raw meat compared to 0.85 in fried meat, and the Thrombogenicity Index was 0.38, in raw meat and 0.98 in fried meat, which shows that undesirable reactions occurred in fried fish muscle. The hypocholesterolemic/hypercholesterolemic ratio was relatively similar in raw muscle (2.68) and fried (2.13), but the total level of unsaturated fatty acids (UFA) in raw fish muscle (81.97%) was lower than that of fried fish (82.59 %). A higher percentage of trans fatty acids was identified in fried fish compared to raw fish. Frying carp meat considerably changed the fatty acid composition of fish meat, increasing the proportion of saturated fatty acids and decreasing the proportion of unsaturated fatty acids.

Key words: *fish meat, thermal treatments, health properties, nutritional indices*

INTRODUCTION

Frying is one of the thermal processes applied both for the purpose of daily food preparation, as well as as a method of food preservation. Many scientific studies certify the fact that thermal treatments change the nutritional composition and health value of fried fish meats, a fact due to processes of degradation of the nutritional factors existing in the raw material, under the impact of the duration of frying as well as the quality of the frying oils, as for example the transformation of

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lipids, generating some reactions that lead to changes in the level of fatty acids. Such reactions are also the basis of the formation of trans fatty acids, with unfavorable nutritional and metabolic effects in the human body. Over time, the consumption of trans fat, associated with the consumption of excess saturated fat, is considered one of the main factors that increase the risk of heart disease, cancer, diabetes and high blood pressure.

MATERIAL AND METHODS

In order to determine the lipolytic changes that appeared after frying in the meat of Romanian carp (*Cyprinus carpio L*), raised in a semi-intensive system in aquatic accumulations in the NE area of Romania, muscles were taken from the dorsal region, from specimens of carp with body weights between 3.0 and 5.0 kg, the carp being harvested in autumn.

According to the consulted technological data, the carp breeding technology was based on natural feed from the sea bream, supplemented with feed mainly based on cereals (corn and wheat flour). (table 1)

Table 1. Composition of feed administered to carp

No. crt.	Feed components	Values and U.M.	Common chemical analyzes	Values obtained
1	Corn flour	43% of the mixture	Moisture	10-15%
2	Triticale flour	16% of the mixture	Dry matter	90-95%
3	Soya flour	20% of the mixture	Crude protein	25,82 %
4	Brewer's yeast	3% of the mixture	Crude fat	4.5-5.3%
5	Shelled sunflower meal	21% of the mixture	Ash	10%
6	Lysine	3.04 g/100g U.S.	-	-
7	Methionine	0.87 g/100g U.S.	-	-
8	PVM mixture	1.0 % of the mixture	-	-

In the semi-intensive carp rearing system, the 3rd and 4th summer carp are additionally fed with combined feed, consistent with the growth objectives and the natural productivity of the carp. In the present experiment, in the carp feed of an extruded feed was used, made up of components of plant origin, so that the cost per kg of feed obtained was as low as possible.

Frying the carp was done in a covered dish, with palm oil, at 170-180°C, for 15 minutes.

The water content of the muscle tissue was determined by the oven drying method (103°C), the total mineral content (ash) was determined by incineration in the calcination furnace (at 550ºC), the total protein content was determined by the Kjeldahl method, the fat content by the Soxhlet method (n-hexane was used as a solvent), and the proportion of fatty acids was determined after a pre-extraction of the fats, according to the standards in force. The separation of methyl esters of fatty acids was carried out by gas chromatography (GCMS), being able to detect saturated fatty acids (SFA) and unsaturated fatty acids (UFA), respectively monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), as well as fractions n -3 and n-6 (Moradi et al., 2011; Oke et al, 2018).

Based on the identified fatty acid content, the n-3/n-6 ratio, PUFA/SFA, MUFA/SFA, PUFA/MUFA and S/P ratios were calculated. In addition, the Atherogenic Index (AI), Thrombogenic Index (TI), Lipid Nutritive Value (VN), trans fat proportion and h/H value (hypo-hypercholesterolemic ratio) were also calculated.

Statistical analysis was performed with ANOVA, with Tukey's test reported at a 5% significance level.

RESULTS AND DISCUSSIONS

The obtained data reveal that differences were recorded between the total number of fatty acids identified in fresh and fried carp meat, the total number of fatty acids being higher in fried meat. Palmitic acid (C16:0) and stearic acid (C18: 0) were the most abundant saturated fatty acids in both categories of carp muscles.

Among the monounsaturated acids (MUFA), oleic acid (C181n-9), palmitoleic acid (C 16:1) and vaccenic acid (C181n-11) stood out quantitatively, in favor of raw meat, and among the polyunsaturated acids (PUFA), linoleic acid (C 18: 2 n-6), docosahexaenoic acid (C22:6 n-3) and α linolenic acid (C18:3 n-3). The fish muscle, regardless of the sample category, contained considerable amounts of unsaturated fats. The dominant fatty acids are listed in the tab. 2.

Table 2. Dominant fatty acids identified in raw and fried carp muscle (*Cyprinus carpio L*)

Specification	**Raw meat (% of total lipids)**	**Fried meat (% of total lipids)**	**Bibliographic references (% of total lipids)**
Saturated Fatty Acids (SFA)			
Lauric acid (C12:0)	0.15±0.09	0.20±0.07	0.03-0.18
Myristic acid (C14:0)	0.73 ±0.16	0.91 ± 0.01	0.65-1.20
Palmitic acid (C16:0)	18.41±.21	23.29 ± 0.17	14.21-23.12
Stearic acid (C18:0)	5.43 ± 0.29	4.35 ± 0.48	2.70-5.84
Arachidic acid (C20:0)	0.86 ± 0.17	0.12± 0.32	0.11- 0.93
Margaric acid (C17:0)	0.43± 0.03	0.18± 0.08	0.10-0.70
Monounsaturated fatty acids (MUFA)			
Palmitoleic acid (C16:1)	5.14 ± 0.72	4.22±0.18	4.18-7.15
Oleic acid (C181n-9)	43.08 ± 0.25	52.0 ± 0.05	13.55-54.16
Vaccenic acid (C181n-11)	4.62 ± 0.26	2.88 ± 0.42	1.93-5.02
Eicosenoic acid (C20 n-1)	3.65 ± 0.15	1.23± 0.05	1.18-3.82
Polyunsaturated fatty acids (PUFA)			
Linoleic acid (C18: 2 n-6)	9.16 ± 0.81	15.6± 0.63	6.12-23.17
α-linolenic acid (C18:3 n-3)	4.56 ± 0.16	2.17± 0.07	0.58-5.23
Behenic acid (C20:2)	0.78± 0.09	0.35± 0.33	0.18-0.92
Eicosatrienoic acid (C20:3 n-3)	0.75± 0.32	0.17± 0.20	0.06-0.91
Arachidonic acid (C20:4)	2.83± 0.13	0.97± 0.60	0.45-3.73
Eicosapentanoic acid (C20:5 n-3)	0.97± 0.17	0.23± 0.08	0.07-1.23
Docosapentaenoic acid (C22:5 n-3)	1.3± 0.62	0.42± 0.70	0.16-6.52
Docosahexaenoic acid (C22:6 n-3)	5.13± 0.07	2.35± 0.22	0.23-5.18
∑SFA	26.01 ± 0.53	29.05 ± 0.35	-
∑MUFA	56.49 ± 0.68	60.33 ± 0.38	-
∑PUFA	25.48 ± 0.73	22.26 ± 0.58	-
∑DHA	5.43 ± 0.43	2.77 ± 0.46	<5%
∑EPA	1.72 ± 0.21	1.63 ± 0.21	<5%
∑Trans	2.16 ± 0.23	4.01 ± 0.21	-
Σω-3	7.15 ± 0.62	4.32 ± 0.61	-
Σω-6	16.42 ± 2.03	10.76 ± 0.03	-
n-3/n-6	0.44	0.29	1:1÷ 1:4
PUFA/SFA	0.97	0.77	-
MUFA/SFA	2.17	2.06	-
PUFA/MUFA	0.45	0.37	-
S / P	0.30	0.35	-
VN	0.37	0.35	-
IA (Aterogenic index)	0.38	0.85	0.35
IT (Trombogenic index)	0.38	0.98	0.72
h/H (Hypo-hypercholesterolemic ratio)	1.02	1.09	2.13-2.68

Notă: IA = [(C12: 0 + (4 × C14: 0) + C16: 0)] ⁄ (MUFA + n−6 PUFA + n−3 PUFA)
IT = (C14: 0 + C16: 0 + C18: 0) ⁄ [(0.5 × MUFA) + (0.5 × n−6 PUFA) + (3 × n−3 PUFA) + (n−3PUFA⁄n−6 PUFA)]
h/H = (C18: 1n−9 + C18: 2n−6 + C20: 4n−6 + C18: 3n−3 + C20: 5n−3 + C22: 5n−3 + C22: 6n−3) ⁄ (C14: 0 + C16: 0)
S / P = (C14: 0 + C16: 0 + C18: 0) / (MUFA + PUFA).

According to the data entered in tab. 2, the mean percentages of C12 (lauric acid) and C14 (myristic acid) were lower in raw fish muscle compared to fried fish muscle. Surprisingly, the amounts for C16 and C18 were found to be higher in raw fish muscle. Of the total polyunsaturated fatty acids, the percentages of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) were (7.67± 2.4%) in raw muscle and (0.87 ± 0.24%) in fried and (0.66 ± 0.21%), respectively in raw muscle and (0.20 ± 0.12%), for fried muscle.

The ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA) in raw fish muscle was 0.97, decreasing to 0.77 in fried fish muscle, and the ratio of Omega 3 to Omega 6 (ω-3/ω-6) it was equivalent to 0.44 in the raw fish sample, and 0.29 in the fried fish muscle.

The level of percentages of trans fatty acids in polyunsaturated fatty acids was 1.28 ± 0.41% in raw muscle and 4.01 ± 0.21% in fried.

Therefore, it is important to also evaluate the health contribution of fatty acids using different indices. These indices could be, for example, n-3/n-6 ratio, S/P ratio, atherogenicity index (IA), thrombogenicity index (IT) and hypocholesterolemic/hypercholesterolemic index (h/H). In the current study, the n-3/n-6 ratio was 0.29 for fried fish and 0.44 for raw fish muscle.

Nutrient indices (IA, IT, S/P, NV and h/H) can indicate the possible health influence of the nutrients in the fish meat consumed. Thus, saturated fatty acids C12: 0, C14: 0 and C16: 0 have an atherogenic effect (increase the concentration of total cholesterol and the LDL fraction), while acids C14: 0, C16: 0 and C18: 0 show thrombogenic activity (stimulate platelet aggregation). Positive effect on human health, due to their anti-atherosclerotic properties, show MUFA and PUFA acids (n-3 and n-6). Consequently, the higher the values of the AI, TI, S / P, NV indices and the lower the h / H ratio, the lower the health quality of the meat (Busra et al., 2018; Estuary et al. 2020).

The values of the atherogenic index (IA) and thrombogenic index (IT) determined in the presented study were significantly higher than those reported in the specialized literature. (Gebremedhin and Berhanu, 2015), with direct reference to freshwater fish meat, respectively the AI for fried meat was 0.85 compared to 0.35 in the literature, and the value of IT was 0.98, compared to 0.72 in the specialized literature.

The ratio of polyunsaturated fatty acids to saturated fatty acids (S/P) was 0.35 in fried fish, a value higher than that of raw fish muscle (0.30). In detail, the Atherogenicity and Thrombogenicity Index was 0.85 and 0.98 respectively for fried fish and 0.38 and 0.68 for raw fish. The hypo/hypercholesterolemic index was 1.09 in fried fish muscle and 1.02 in raw fish muscle, compared to values between 2.13 and 2.68, existing in the specialized literature. Therefore, the ratios were considerably modified due to the frying of Romanian carp meat. In addition, as shown in tab. 3, fried fish also recorded the highest concentration of saturated fatty acids (29.05%), compared to raw meat (unfried-26.01%).

Table 3. Comparison of the composition² (%) of fatty acids in raw and fried carp muscle (*Cyprinus carpio L.)*

Specification	Raw meat ($\bar{X} \pm S_{\bar{X}}$)	Fried meat ($\bar{X} \pm S_{\bar{X}}$)	Meaning P¹
∑SFA	26.01 ± 0.53	29.05 ± 0.35	*
∑UFA	81.97 ± 5.16	82.59 ± 4.17	ns
∑MUFA	56.49 ±0.68	60.33 ± 0.38	*
∑PUFA	25.48 ± 0.73	22.26 ± 0.58	*
∑DHA	5.43 ± 0,43	2.77 ± 0.46	**
∑EPA	1.72 ± 0.21	1.63 ± 0.21	ns
∑Trans	2.16 ± 0.23	4.42 ± 0.65	**
Σω-3	7.15 ± 0.62	3.12 ± 0.33	**
Σω-6	16,42 ± 2.03	10.76 ± 0.03	**

Note: p¹p-values for means and standard deviations were taken from independent sample t-tests.
n.s.-p>0.05; **P<0.01; ***P<0.0001.
Note: ²composition expressed as a percentage of total fatty acids

Food frying, regardless of its invasive degree of nutritional transformation of the raw material, has gained more and more acceptance from consumers, with "ready-to-eat" or "medium-to-eat" products being bought and consumed all over the world, even if many of the physiological disadvantages are recognized, such as the destruction of vitamins and microelements, the denaturation and degradation of fats and proteins. Fried products are appreciated, in particular, for their crispy texture, the volatile aromas due to frying, their pleasant, golden taste and color. Young consumers, especially those who follow fast food or street food, although they can be easily informed, neglect the fact that, during excessive cooking, the oils and fats used for frying degrade and many reactions occur, especially oxidation which have resulting in numerous products of the modified fatty acid type. Geometric isomerization of double bonds leads to the formation of trans fatty acids (Jayasena et al., 2018; Karimian-Khosroshahi et al., 2016).

In conclusion, it is very important to remember the fact that the general nutritional qualities of fats depend on the inclusion of monounsaturated fatty acids in the ratios, along with the results of invasive transformation processes, such as the thermal one. In this case, the IA, IT and h/H values are sufficiently suggestive, indicating the potential health effects of fatty acids for human health.

It is known that a high Atherogenicity Index (IA) as well as increased values of the Thrombogenicity Index (IT) are involved in the formation of atheroma and stimulate the aggregation of platelets in the human cardiovascular system. Therefore, foods that generate lower values of these indices are desirable to enter the human diet, as they are the guarantor of the prevention of heart disorders and the correct functioning of the cardiovascular system (Wang et al., 2015; Oluwaniyi et al., 2017).

The frying activity also generates trans fats, at the same time reducing the content in DHA (from 5.43 ± 0.43% to 2.77 ± 0.46%, statistically significant differences) and EPA, from 1.72 ± 0.2% in raw muscle, at 1.63 ± 0.21% in fried muscle. The results were probably also influenced by the fact that this type of fatty acids were not present in frying fats.

Trans fats, formed especially in the heat treatment process of food (4.01 ± 0.21% in fried meat, compared to 2.16 ± 0.23% in raw meat), are considered as factors that increase the risk of heart disease, cancer, diabetes and hypertension. In order to reduce these effects on health, the FAO-UN recommends, starting in 2014, that every country has a food risk inspection system (FAO, 2010; FAO, 2014; FAO, 2016).

CONCLUSIONS

Awareness of the fact that the diet of native fish meat, such as the Romanian carp (*Cyprinius carpio L.*) has a whole series of nutritional and health benefits is growing. Nutritionists have already established the role of bioactive compounds in fish meat that support the growth and functioning of the human body, evaluating their therapeutic potentials that help maintain health and alleviate disease states.

Therefore, the constant consumption of fish meat and derived products brings into the human metabolism a series of bioactive constituents with potential therapeutic effects that can improve the health of the population and the quality of life.

The various thermal treatments, either for the purpose of culinary preparation of the food or for the purpose of preservation, as observed in the experiments carried out, lead to the reduction of the beneficial effects of the bioactive compounds, reducing many physiological mechanisms, such as antioxidant activity, hormonal actions and improving the functioning of the system immune.

Minimally invasive culinary treatments performed on carp meat (steam cooking, moderate boiling, scalding, etc.) offer the possibility of keeping the bioactive constituents at an optimal level as nutritional and therapeutic values for the consumer. A whole range of bioactive constituents such as proteins, lipids, minerals, vitamins and other nutrients in fish meat also possess important therapeutic potentials, being associated with high amounts of long-chain omega-3 polyunsaturated fatty acids (PUFA) and omega-6.

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