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Quality-related changes of biologically active lipids in bluefish muscle tissue after cooking

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The aim of the present study was to evaluate the effect of different cooking methods (steaming, grilling, conventional baking and microwaving) on total lipids, fatty acid composition, fat soluble vitamins (A, D_3 and E), and cholesterol contents of bluefish tissue (*Pomatomus saltatrix*) from the Black Sea coast.

There were no significant differences in the amounts of total lipids between raw, steamed, grilled and oven baked samples. In contrast, there was a significant increase in the total lipid content of microwaved bluefish, probably due to the significant decrease in moisture content. Fatty acids (FA) groups were affected by all thermal treatment, but their distributions kept similar pattern: SFA>MUFA>PUFA. All three fat soluble vitamins showed significantly higher values during culinary treatment, with the exception of vitamin E after grilling. However, all cooking methods were found to be appropriate culinary treatment, which preserves well nutritional lipid quality of bluefish meat.

Keywords*: fat soluble vitamins, fatty acids, thermally treatment, Pomatomus saltatrix*

INTRODUCTION

Marine fish are a very good source of several biologically active compounds as fat soluble vitamins, unsaturated fatty acids and cholesterol. The vitamins control a variety of processes in human organism. On the other side, fish lipids were known as rich of active substances with cardio protective role. The most active constituents are identified to be n3 polyunsaturated fatty acids (n3 PUFAs), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [1].

Bluefish (*Pomatomus saltatrix*) is a marine, pelagic fish, which is found in most seas and oceans around the world. It is known for its delicious taste and high nutrition quality. Many studies observed the information about PUFAs content and fat soluble vitamins' in raw fish edible tissue, which have limited application on human health. Traditionally culinary treatment of this species involves grilling and baking. Temperature processing of fish fillets is applied to inactivate pathogenic microorganisms and enhances its taste, but this treatment influences the fat soluble vitamins and essential fatty acids contents. It is known that many of the biologically active substances (vitamins etc.) degrade in presence of oxygen and under the influence of high temperatures. Therefore, many studies focused their research to calculating the changes in content of these components in fish tissues, after thermally treatment [2 - 6]. The most commonly used methods of culinary processing of edible fish tissue are steaming, grilling, oven baking, microwave oven treatment. It has been found, however the changes in nutrient content depend on one side from the variety of heat treatment, but the other side - from fish type [7].

There is limited information in the scientific literature about changes in lipid composition of the Black Sea bluefish edible tissue occurring after cooking process.

EXPERIMENTAL

Sample preparation

Fifteen Black Sea bluefish specimens were purchased from the local Varna fresh fish marketplace. In the laboratory fish was filleted with the skin and the fillets were randomly divided into five groups: first (n = 6) - analyzed in raw state; a second (n = 6) was analyzed after steaming (in a steamer for 10 min, 90°C), the third (n = 6) – after grilling (on a grill for 15 min, 220°C), the fourth (n = 6) – after baking (on an oven for 25 min, 200 °C) and the fifth (n = 6) – after microwaving (on a microwave oven for 15-20 min, ~800 W). After processing, the samples were weighed in order to obtain the weight loses compared with raw state.

Moisture analysis

The moisture content of raw and cooked samples was determined by the AOAC method and calculated as weight loss [8]. The results were calculated as percentage losing weight after drying the samples.

Vitamin's and cholesterol analysis

Fat soluble vitamins (A, D_3 and E) and cholesterol were determined simultaneously using

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HPLC system (Thermo Scientific Spectra SYSTEM) equipped with Synergi 4μ Hydro-RP 80A pore 250×4,6 mm reversed-phase column. The sample preparation was performed using the method of Dobreva et al. [9]. The received data were calculated and expressed as μg per 100 g wet weight (μg.100g^{-1}ww).

Total lipid and fatty acid analysis

The extraction of total lipids from analyzed edible fish tissue was done according to Bligh & Dyer method [10]. Total lipid (TL) content was determined for each group of sample (n=6) and the results were presented as g per 100g wet weight (g.100g^{-1}ww).

Fatty acid methyl esters were prepared by base catalyzed transmethylation and directly analyzed by gas chromatography system, model FOCUS Gas Chromatograph A3000, equipped with Polaris Q MS detector (Thermo Scientific, USA). The chromatography system was equipped with capillary column TR-5 MS, 30m length, 0.25mm i.d. The observed data were calculated and expressed as the percentage of total fatty acids.

Statistical analysis

The received chromatography data were statistically analyzed using Graph Pad Prism 6 software. The nonparametric test - one-way ANOVA statistical analysis, was used for calculation of differences between raw and cooked by different techniques samples (significant at $p<0.05$). The recalculated results were presented as mean and standard deviations.

RESULTS AND DISCUSSION

Moisture content

The moisture content of all bluefish samples (cooked and raw) was determined and compared. The highest percentage showed the raw sample (56.5%). During all the processes of cooking a significant decrease with raw tissue was observed. The established amounts for thermally processed fillets were – 62.10 % in steamed, 59.40% in grilled, 60.0% in oven cooked and 49.19% in microwaved samples. These results are in agreement with our previous research for Shad fillets [11]. The other authors presented similar research and conclusions for cooked trout edible tissue [3].

Fat soluble vitamins' and cholesterol contents

The effect of different types of heat treatment on fat soluble vitamins (A, D_3 and E) and cholesterol contents was examined in bluefish edible tissue. Traditional thermal techniques such as steam processing, grilling, oven cooking and microwaving were selected for the preparation of fish fillets. The received results are presented in Table 1. The presented data shows that the varied types of thermal treatment of fish tissue influenced in different ways the content of the three fat soluble vitamins and cholesterol. Only in the case of vitamin D_3 content, we observed decreases after all methods of heat treatment.

A statistically significant reduction in the levels of vitamin D_3 of the treated samples compared to the untreated was found in grilling - 32% ($p<0.01$) and microwaving - 47% ($p<0.001$) (Table 1). For the other thermal treatments, the differences are statistically insignificant ($p> 0.05$). The amount of these analyte in processed fish fillets remains almost unchanged after two different cooking methods – steaming (12% decrease) and oven cooking (10% decrease) ($p>0.05$). The temperature influenced the vitamin D_3 levels on a very small extent compared to the other two vitamins.

On the other hand, vitamin A amount decreased significantly after process of steaming and oven cooking ($p<0.001$) with 25.3% and 22.6%, respectively (Table 1). But after other two types of thermal processing he remains almost unchanged. The grilling and microwaving processes did not affect the vitamin A levels in the fish tissue - 146.2 μg. 100 g^{-1} ww in the raw state, compared to 154.4 μg. 100 g^{-1} ww and 155.3 μg. 100 g^{-1} ww, respectively ($p>0.05$).

Table 1 Fat soluble vitamin's and cholesterol contents in raw and cooked fish fillets

Analyte	Black Sea Bluefish				
	raw	steamed	grilled	oven cooked	microwaved
Vitamin A, μg.100g^{-1}ww	146.2±3.7	109.0±12.1[a]	154.4±16.7	113.2±14.2[a]	155.3±17.4
Vitamin D_3, μg.100g^{-1}ww	40.9±2.3	35.8±7.4	27.7±3.4[a]	36.8±4.3	22.4±2.8[a]
Vitamin E, mg.100g^{-1}ww	4.4±0.3	4.8±0.5	5.3±0.5[b]	2.1±0.2[a]	5.6±0.6[b]
Cholesterol, mg.100g^{-1}ww	41.40±3.1	55.74±6.4[b]	45.09±6.2	62.43±5.4[a]	80.28±9.1[a]

[a] $p<0.001$ raw vs cooked; [b] $p<0.05$ raw vs cooked

The influences of selected types of heat treatment on bluefish edible tissue were also monitored for vitamin E levels (Table 1). The most significant decrease in the amount of vitamin E (by 50%) was after cooking the raw fish tissue in oven. Like vitamin D, and vitamin E showed increases in its amount after two of the heat treatment methods – on grilling and microwaving with almost 20 %. The reasons are probably the same - the changes are related with those in moisture content of the sample, which improve on the hydrolysis rate of the treated tissue. On the other side, the process of steaming does not change statistically the levels of this vitamin ($p > 0.05$).

The data for cholesterol content shows different behaviors. Its amount increased after four type of thermal processing on fish tissue. This correlated with changes in moisture and total lipids contents of the analyzed samples.

In the scientific literature it is observed a discrepancy in the effect of different types of thermal processing on the fat soluble vitamin contents in edible tissue of fish [2, 4, 5, 7, 12]. A study of the influence of variety cooking methods (grilling, microwaving, oven baking and frying) on changes in vitamin A and vitamin E levels in African catfish tissue was reported by Ersoy and Özeren [5]. They found significant differences in the content of both analytes after all thermal treatments. The slightest decrease in vitamin A was observed after the process of microwaving (10%), and the strongest - after baking in oven (36%). The same authors also found significant changes in the vitamin E content. The data showed that the quantity of vitamin E was the most influenced in the case of oven baking - vitamin E levels are increased several times (4.5 times). In the other two processing methods, the changes are also high - grilling and microwaving shows increases of 73% and 53%. When compared to our results, we can say that the changes they made relative to raw tissue are much higher than those observed in our study (Table 1).

The scientific group of Erkan found out losses of vitamin A (75%) and vitamin E (55%) levels in steamed tissue of horse mackerel, which is in agreement with our results [6]. On the other side Mattila et al. reported decreased amount below 10% for vitamin D_3 in herring tissue after oven baking process, which is also close to our results [2].

Total lipids and fatty acid composition

The TL contents in raw and processed edible tissue of bluefish are presented and compared in Table 2. The observed data showed different influence of the cooking techniques on TLs in analyzed samples. Only one is the significant increase of analyte - for microwaved fish fillets, compared to the raw.

The other authors comment that the changes in TL amounts after thermal processing (steaming and roasting) strongly depend on the fish species, the temperature, the size of the sample and the heatable surface area. The data are in accordance with those by other authors. Gladyshev et al. and Gülgün et al. observed losses of lipids under the influence of heat treatment on edible tissue of rainbow trout and king salmon [13, 14].

As a result of the research, on raw and processed bluefish fillets were observed changes also and in the FA composition of the samples. In Table 2 we presented the results for the major FA groups and their ratios as a percentage of total FAs. They were calculated and compared after the four processes of cooking methods on bluefish fillets. The considered scientific groups presented this effect of heat treatment on FA composition of various fish species. They reached very different conclusions [2, 4, 13, 14].

The SFA was the most abundant (38.86 %) FA group in raw samples, followed by MUFA (33.30 %) and PUFA (27.84 %). This distribution was also confirmed in the processed fish fillets - in the four different methods of preparation (Table 2). These results are in agreement with those of other authors [12]. However, the data obtained, shows different changes in the groups, depending on the applied processing method. The SFA group shows no significant changes after all cooking technics. But the other groups – MUFA and PUFA showed different behaviors. The MUFA significantly decreased ($p<0.05$) in the steamed fillets. As the PUFA increased ($p<0.05$) after process of oven cooking, compared with raw bluefish tissue. In two of the thermal treatments, all three FA groups were significantly changed – oven cooking and microwaving (Table 2).

The other authors established significant decreases in the levels of PUFA and MUFA groups. Larsen et al. was found for steaming salmon decreasing of MUFA and PUFA levels [15]. These differences of the FA groups, after various thermal treatments, were attributed in most cases to the tissue specificity of the fish species.

The sum of n3 PUFAs slightly decreased after steam cooking the bluefish fillets. The n6 PUFAs showed different behavior – they increased after the same process. But the changes in two cases were not significant ($p>0.05$).

The sum of n3 FA content was found to be higher than n6 FAs in all - raw and cooked fish fillets.

Table 2 Total lipid contents and fatty acid groups in raw and cooked fish fillets

Analyte	Black Sea Bluefish				
	raw	steamed	grilled	oven cooked	microwaved
Total lipid, g.100g^{-1}ww	4.05	4.046	4.33	4.22	6.06[a]
Σ SFA	38.86	42.00	36.88	36.62	36.50
Σ MUFA	33.30	30.55	32.21	32.03	34.30
Σ PUFA	27.84	27.45	30.91	31.35	29.20
Σ n3	21.44	20.55	24.80	26.33	23.09
Σ n6	6.90	7.35	6.61	6.50	6.61
n-6/n-3	0.32	0.36	0.27	0.26	0.29
PUFA/SFA	0.63	0.65	0.84	0.86	0.80

[a] $p<0.001$ raw vs cooked

The nutritional value of fats often characterized with ratios of PUFA/SFA and n6/n3. The most Health organizations have nutritional recommendations connected with fatty acid content of foods [16, 17]. They considered the PUFA/SFA ratio in human diets should be above 0.45 and the n6/n3 ratio should not exceed 4.0.

In the present research were observed changes in the two discussed ratios. The thermally processed samples showed significantly higher ($p<0.05$) PUFA/SFA and n6/n3 ratios, compared with raw. And in two cases they were over the minimum of recommended values.

CONCLUSIONS

The impact of the four different cooking methods on fat soluble vitamins, cholesterol and fatty acids composition of bluefish fillets were investigated.

Cholesterol content increased after steaming, conventional baking and especially microwaving.

All three fat soluble vitamins showed significantly higher values during culinary treatment, with the exception of vitamin E after grilling. Vitamin A and E presented highest increase after microwaving and grilling, while vitamin D_3 – after steaming.

Most abundant FAs in the polyunsaturated FA group were eicosapentaenoic acid (C20:5 n-3, EPA) and docosahexaenoic acid (C22:6 n-6, DHA), which accounted more than 50% of total PUFA. The raw bluefish edible tissue shows the FAs pattern in the order: SFA>MUFA>PUFA, which was validated after the steaming, grilling, oven baking and microwaving processes.

Among the methods used, microwave cooking showed most significant effect on the analysed fish tissue, which resulted in 50% weight and 30% moisture loss, thus affecting the content of lipid components.

The nutrition of lipids of the Black Sea Bluefish tissue was characterized with high levels of fat soluble vitamins, n3 and n6 FAs and good cholesterol content. And the conclusion is that the positive beneficial effect of fish lipids based on n3/n6 and PUFA/SFA ratios, and fat soluble vitamins' content are preserved after that treatment.

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