CONTROLE DE ODORES EM PRODUTOS ALIMENTARES USANDO FIBRAS ALIMENTARES

ODOR CONTROL IN FOODS USING DIETARY FIBERS

РЕГУЛИРОВАНИЕ ЗАПАХА В ПИЩЕВЫХ ПРОДУКТАХ ИСПОЛЬЗОВАНИЕМ ПИЩЕВЫХ ВОЛОКОН

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RESUMO

O objetivo do presente trabalho é determinar a capacidade do farelo de trigo de eliminar o cheiro desagradável de peixe através da conversão de substâncias voláteis em não voláteis, bem como o efeito do farelo de trigo no valor nutricional de amostras tratadas termicamente de tecido muscular picado de peixe. Os principais métodos de pesquisa incluem o método Kjeldahl, para determinar o conteúdo de extratos nitrogenados, a cromatografia gás-líquido para determinar a composição de ácidos graxos e o organismo de teste de ciliado de *Tetrahymena pyriformis* para determinar o valor biológico relativo. Como resultado, a capacidade das fibras alimentares de eliminar um cheiro desagradável de peixe pela conversão de extrativos nitrogenados voláteis em não voláteis foi demonstrada pelo exemplo do farelo de trigo: uma série de experimentos realizada para identificar a dependência do conteúdo de óxido de trimetilamina e nitrogênio de bases voláteis em amostras de tecido muscular picado da navaga, dependendo da proporção de farelo de trigo adicionado, verificou-se que em todas as amostras há uma diminuição no conteúdo de extrativos com um aumento na fração de massa de farelo de trigo. Além disso, o farelo não moído contribui mais ativamente para o processo de neutralização do odor. Foram identificadas a composição dos ácidos graxos dos lipídios da navaga do Extremo Oriente *Eleginus gracilis*, farelo de trigo e sua mistura, e o efeito no valor biológico relativo determinado no organismo de teste de amostras experimentais após tratamento térmico (escaldamento e fervura).

Palavras-chave: farelo de trigo, extrativos nitrogenados, composição de lipídios dos ácidos graxos, valor biológico relativo.

ABSTRACT

The aim of the present work is to determine the ability of wheat bran to eliminate an unpleasant fish smell by converting volatile extractive substances to nonvolatile ones, as well as the effect of wheat bran on the nutritional value of thermally treated samples of minced muscle tissue of fish. The main methods for research include the Kjeldahl's method for determining the content of nitrogenous extractives, the gas-liquid chromatography for determining the composition of fatty acids, and the test organism of *Tetrahymena pyriformis* ciliate for determining the relative biological value. As a result, the ability of dietary fibers to eliminate an unpleasant fish smell by converting volatile nitrogenous extractives into nonvolatile ones has been shown by the example of wheat bran: in a series of experiments to identify the dependence of the content of trimethylamine oxide and nitrogen of volatile bases in samples of minced muscle tissue of the navaga, depending on the proportion of added wheat bran, it has been found that in all samples there is a decrease in the content of extractives with an increase in the mass fraction of wheat bran. Moreover, unmilled bran more actively contributes to the process of neutralizing odor. The fatty acid composition of the lipids of the Far Eastern navaga *Eleginus gracilis*, wheat bran and their mixture, and the effect on the relative biological value determined on the test organism of experimental samples after thermal treatment (scalding and boiling) have been identified.

Keywords: wheat bran, nitrogenous extractives, fatty acid composition of lipids, relative biological value.

АННОТАЦИЯ

Целью работы являлось определение способности пшеничных отрубей устранять неприятный рыбный запах путем перевода летучих экстрактивных веществ в нелетучие, а также влияние пшеничных отрубей на пищевую ценность термически обработанных образцов из измельченной мышечной ткани рыбы. В качестве основных методов для проведения исследований были выбраны: рекомендации Кельдаля для определения содержания экстрактивных азотистых веществ, газожиждкостная хроматография для определения состава жирных кислот, тест-организм инфузория *Tetrahymena pyriformis* для определения относительной биологической ценности. В результате была показана способность пищевых волокон на примере пшеничных отрубей устранять неприятный рыбный запах путем перевода азотистых летучих экстрактивных веществ в нелетучие: в серии экспериментов по выявлению зависимости содержания триметиламинооксида и азота летучих оснований в образцах из измельченной мышечной ткани наваги, в зависимости от доли добавляемых пшеничных отрубей, было установлено, что во всех образцах наблюдается снижение содержания экстрактивных веществ с увеличением массовой доли пшеничных отрубей. Причем неизмельченные отруби более активно способствуют процессу нейтрализации запаха. Определен жирнокислотный состав липидов дальневосточной наваги *Eleginus gracilis*, пшеничных отрубей и их смеси, и влияние на относительную биологическую ценность, определенную на тест-организме, экспериментальных образцов после термической обработки (бланширование и варка).

Ключевые слова: пшеничные отруби, азотистые экстрактивные вещества, жирнокислотный состав липидов, относительная биологическая ценность.

1. INTRODUCTION

The development of the technology of products from minced fish is promoted by the wide possibilities of carrying out various modifications on its basis with the aim of regulating nutritional value and creating enriched and functional food products. The traditional raw materials for minced meat production are fish with predominantly light muscle tissue, low-fat content, and high content of myofibrillar proteins (Hagen and Johnsen, 2016; Murthy *et al.*, 2017; Gonçalves and Salas-Mellado, 2018; Cardoso *et al.*, 2019; Chen *et al.*, 2020; Gu *et al.*, 2020).

The authors had carried out the studies which allowed establishing that when using two indicators: the conditional protein coefficient (C_p – the ratio of nitrogen of the protein salt-soluble fraction to nitrogen of the water-soluble fraction) and the structure formation coefficient (C_{st} – the ratio of the nitrogen content of the salt-soluble fraction to total nitrogen), it was possible to qualify how much fish was suitable for minced meat production (Bidenko and Rambesa, 1978). With $C_p < 1$ and $C_{st} < 0.2$, poorly formed minced meat with rigid consistency (e.g., pollock, blue whiting, cardinalfish) is obtained. At $C_p 1 - 1.2$ and $C_{st} \sim 0.2$, the formability of minced meat increases (e.g., Baltic cod, Macrourus icefish). The best raw material for obtaining well-formed minced meat with a high ability to hold water is fish with $C_p > 1.2$ and $C_{st} > 0.2$. These species include herring, ivasi,

horse mackerel, and scomber mackerel. These are just those types of objects that contain a significant amount of dark muscle tissue. Unlike light muscles, dark ones consist of thin dark fibers, the space between which is filled with sarcoplasm with a high content of glycogen, myoglobin, cytochrome C, i.e., substances that accelerate the oxidation of lipids (Kolakovskii, 1991; Lee, Seki, and Kato, 1990; Obatake, 1985). The total lipid content in dark muscles is 5 to 20 times greater than in light ones.

All this, including high iron content (up to 75 %), which is not part of the myoglobin heme, and increased enzymatic activity contribute to the susceptibility of dark muscles to rapid oxidation, and to the formation and rapid growth of an unpleasant odor. Moreover, the deeper the degree of dressing of raw materials is, the longer the contact with atmospheric oxygen is, and the more intense the oxidation processes are (Boitsova, Doroshenko, and Shipova, 2001).

At the same time, certain fish species with predominantly light muscles, low-fat content, low enzymatic activity, and practically not subject to oxidation, are also not suitable for the production of good quality minced meat. Thus, a typical representative of codfishes, pollock (*Theragra chalcogramma*), is characterized by a high content of trimethylamine oxide in the light muscles (TMAO up to 10.80 mg/g). Immediately after catching, the TMAO breaks down into trimethylamine (TMA) and formaldehyde in muscle

tissue of pollock, which have a significant effect on the specific taste and aromatic properties of minced meat (Crapo and Himelbloom, 1994; Greene and Bernatt-Byrne, 1990).

These specific features of pollock are among the reasons for the undesirable use of pollock for obtaining unwashed minced meat, and it is used only for the production of surimi.

Surimi technology involves mincing fish muscle tissue and washing it with water to remove water-soluble components: sarcoplasmic (water-soluble) proteins, enzymes, nitrogenous extractives, including TMAO, TMA, and formaldehyde. Surimi practically consists only of myofibrillar (salt-soluble) proteins, has no negative smell and taste. Surimi is the main raw material for the production of structured analog products. However, its output is only from 12 to 15 % by weight of the whole fish (Li and Chen, 2009; Filomena-Ambrosio *et al.*, 2016; Iwashita *et al.*, 2016; Li *et al.*, 2016; Konno, 2017; Houjyo *et al.*, 2017; Sipailiene, 2017; Zhang *et al.*, 2017; Ma *et al.*, 2017; Jin *et al.*, 2018; Gao *et al.*, 2018).

It is known that dietary wheat fiber, wheat bran (WB), has a sorption ability, including in relation to a number of metals (Guillon and Champ, 2000; Lin *et al.*, 2019; Zhang, Huang and Ou, 2011).

It has been suggested that substances adding an unpleasant smell to minced fish products can also be absorbed by dietary fiber. In addition, there are a number of works devoted to the introduction of dietary fiber into the composition of minced meat of surimi from other fish species: Alaska pollock (Alakhrash, Anyanwu, and Tahergorabi, 2016; Debusca, Tahergorabi, Beamer, Matak, and Jaczynski, 2014), silver carp (Yin *et al.*, 2019), bighead carp (Alipour, Rezaei, Shabanpour, and Tabarsa, 2018, 2019).

The purpose of these studies is to determine the ability of WB to eliminate an unpleasant fish smell by converting volatile extractive substances to nonvolatile ones, as well as the effect of WB on the nutritional value of thermally treated samples of minced muscle tissue of fish.

2. MATERIALS AND METHODS

For the model system, minced meat of the muscle tissue of the Far Eastern navaga (*Eleginus gracilis*) as an object containing light and dark muscles, up to 0.002 mg/g of formaldehyde, and 0.5 – 1.4 % of lipids, was selected. These

components, in addition to the formation of an unpleasant odor, contribute to a decrease in the water-holding ability of the protein due to the binding of amine groups and the formation of methylene-amine complexes.

WB was used as a sorbing complex, part of which had been preliminarily milled to sizes less than 250 microns, and the other part had been left to industrial production. The main part size was from 350 to 600 microns.

The content of nitrogenous extractives was determined by Kjeldahl's method (Regenstein and Regenstein, 1984). It was based on the organic matter oxidation during combustion in sulfuric acid in the presence of a catalyst, the distillation of ammonia formed by steam, trapping it with a solution of sulfuric acid and determination of the nitrogenous substances content by titration.

To determine the composition of lipid fatty acids, hydrolysis of lipids isolated by the Bligh-Dyer method (Bligh and Dyer, 1959) and methylation of higher fatty acids by the method of Metcalf and Schmitz (Metcalf and Schmitz, 1961) were performed. The obtained fatty acid methyl esters were analyzed by gas chromatography on a G-180 Yanako device (Japan) and a Shimadzu gas-liquid chromatograph using Argon gas. Identification was carried out according to the methods of Miwa (1963); Cfrreau and Dubacq (1978).

To determine the relative biological value, the test organism of the *Tetrahymena pyriformis* ciliate was used. The ciliate has small body sizes: 20 by 50 microns, the weight of one tetrahymena is $1.8 \cdot 10^{-9}$ g. It gives 7.51 divisions per day, which is directly dependent on such vital factors as growth and stimulation of vital processes. The ciliate is cultivated on a protein nutrient medium, and the optimal cultivation temperature is 25 °C. For the analysis, 0.02 ml of a three-day culture and 1 – 3 g of the test product were used. The duration of the analysis was four days.

The relative biological value and biological activity of the ciliate were compared with the whole milk. The essence of the method for determining biological activity is to establish the moment of the growth stationary phase of the ciliate at the limiting level of samples of the studied and standard samples and to determine the rate of reproduction in the studied sample in comparison with the standard one. Exact quantitative accounting of the grown individuals was carried out in the Gorjaev's count chambers. The samples that had not shown death or other pathological changes in tetrahymena within four days were left for further

incubation for up to seven days to identify the possibility of long-term negative consequences (Ignatiev and Myagkov, 1980; Mohr, 1981; Shulgin, Shulgina, and Petrov, 2006, pp. 83-95).

The reliability of the obtained experimental data was ensured by the method of mathematical statistics. Reliability is 0.90 – 0.95 (P), and the confidence interval is $\pm 5\%$.

3. RESULTS AND DISCUSSION

In a series of experiments to identify the dependence of the content of TMAO and volatile base nitrogen (VBN) in samples of minced muscle tissue of navaga, depending on the proportion of added WB, it was found that there was a decrease in the content of extractive substances with an increase in the mass fraction of WB in all samples (Figure 1, Figure 2). Moreover, unmilled bran more actively contributes to the process of neutralizing odor than milled one up to a size of 250 microns, despite the large sorption surface. Obviously, this is due to the violation in the milling process of not only physical dimensions but also the chemical structure of bran, which affects their ability to sorb volatile bases and TMA.

Wheat bran also has a positive effect on the fatty acid composition of the minced meat. The nutritional value of fish lipids is characterized by the presence of higher polyunsaturated fatty acids, which are necessary for normal human life. There are about 49 % of them in the navaga lipids (Table 1). Moreover, such types of thermal treatment as boiling in water and scalding practically do not influence the reduction of their quantity. The recorded fluctuations are within the error limits. WBs themselves also contain polyenoic acids, especially a large amount of linoleic acid (18:2 ω 6 – up to 51.88 %), which is characteristic of plant raw materials.

The addition of 5 % of WB to the minced muscle tissue of navaga leads to an increase of four times in the mass fraction of linoleic acid, and of linolenic acid (18:3 ω 3) – 1.5 times. The content of other polyunsaturated fatty acids (arachidonic 20:5 ω 3, eicosapentaenoic 22:5 ω 3, and docosahexaenoic 22:6 ω 3) is practically unchanged and does not depend on the thermal treatment method.

The presence of WB practically does not affect the content of saturated fatty acids. Their total amount decreases somewhat when scalding and, to a greater extent, when cooking in water, apparently due to the transition of the fat fraction into the broth.

Among monoenoic fatty acids, the oleic one (18:1 ω 9) and its isomer (18:1 ω 7) are the most characteristic of fish. Their ratio should be 2:1, and this ratio, despite natural minor losses during thermal treatment, remains unchanged.

Considering that the properties of odor are determined by organoleptic sensations, experimental samples of minced muscle tissue of navaga with the addition of 5 % of WB have been prepared. Products of 6x3x3 size were formed from the mixture and were thermally treated. Other components of the formulation were not involved in the experiment.

The results of the organoleptic evaluation confirmed the data of the chemical tests. Tasters noted a pleasant smell with a bread aroma and a meat-like taste.

The relative biological value of the experimental samples in comparison with the standard one (whole cow's milk), determined on the test organism, shows a slightly lower result (Table 2). However, the addition of WB only slightly reduces the relative biological value compared with the muscle tissue of fish without WB (by 2 – 6 %). At the same time, the thermal treatment of the experimental samples (scalding, frying) promotes more active cell growth.

4. CONCLUSION:

It has been found that wheat bran sorbs volatile extractive nitrogenous compounds (TMAO and VBN), contributing to the neutralization of fish smell. In this case, additional milling of WB is not required. Moreover, the addition of WB leads to an increase in the mass fraction of essential linoleic and linolenic fatty acids, which is characteristic of plant raw materials. In this case, the content of other polyunsaturated fatty acids is practically unchanged and does not depend on the thermal treatment method. The obtained results and the established VBN suggest that ready-made foods made from minced muscle tissue of fish with the addition of WB will have high nutritional value.

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Figure 1 - Dependence of the content of TMA in minced fish on the mass fraction of WB

Figure 2 - Dependence of the content of volatile bases in minced fish on the mass fraction of WB

Table 1 - Composition of fatty acids of navaga muscle tissue (MT) and WB, in % of the total fatty acids

Fatty acids	MT	MT after boiling	MT after scalding	MT with WB	MT with WB after boiling	MT with WB after scalding	WB
1	2	3	4	5	6	7	8
12:0	0.11	0.12	0.10	0.10	0.10	0.14	0.03
14:0	1.80	1.94	1.65	1.38	1.28	1.85	0.12
i-15:0	0.14	0.14	0.12	0.10	0.10	0.12	0.02
15:0	0.63	0.61	0.57	0.52	0.47	0.55	0.12
i-16:0	0.13	0.14	0.14	0.12	0.11	0.12	0.01
16:0	19.69	19.52	19.31	19.05	19.03	20.20	16.47
i-17:0	0.38	0.33	0.35	0.29	0.28	0.26	-
ai-17:0	0.35	0.36	0.33	0.29	0.28	0.26	0.04
17:0	0.61	0.60	0.58	0.54	0.50	0.51	0.10
i-18:0	0.19	0.18	0.17	0.15	0.15	0.10	-
18:0	4.26	4.75	4.25	3.72	3.54	4.02	1.50
19:0	0.10	0.11	0.12	0.12	0.12	0.12	0.19
20:0	0.14	0.14	0.11	0.12	0.12	0.17	0.10
Amount of saturated	28.53	29.04	27.80	26.50	26.08	28.48	18.74
14:1	0.14	0.13	0.10	0.10	0.10	0.13	0.08
15:1	0.23	0.12	0.10	0.10	0.10	0.10	0.05
16:1 ω 7	4.75	4.74	4.50	3.99	3.68	3.97	0.37
16: ω 5	0.28	0.28	0.26	0.25	0.24	0.23	-
17:1	0.70	0.65	0.63	0.56	0.53	0.53	-
18:1 ω 11	0.24	0.27	0.24	0.23	0.22	0.22	-
18:1 ω 9	8.42	8.72	8.72	9.05	9.91	11.35	23.46
18:1 ω 7	4.36	4.67	4.29	4.11	3.78	3.60	0.70
1	2	3	4	5	6	7	8
18:1 ω 5	0.21	0.26	0.20	0.19	0.18	0.17	0.02
19:1	0.25	0.12	0.18	0.17	0.20	0.10	0.03
20:1 ω 11	0.29	0.30	0.23	0.22	0.18	0.30	0.21
20:1 ω 9	0.37	0.36	0.28	0.36	0.39	0.53	0.34
20:1 ω 7	0.21	0.16	0.19	0.22	0.16	0.21	-
22:1 ω 11	0.46	0.36	0.37	0.32	0.24	0.53	-
24:1	0.27	0.26	0.34	0.25	0.32	0.32	-
Amount of monoenoic	21.18	21.40	20.63	20.12	20.23	22.29	25.26
16:2 ω 4	0.78	0.79	0.58	0.67	0.61	0.64	-
18:2 ω 9	0.18	0.18	0.17	0.19	0.19	0.21	-
18:2 ω 6	1.17	1.24	1.06	4.49	10.94	11.46	51.88
18:2 ω 4	0.22	0.23	0.19	0.22	0.17	0.14	0.04
18:3 ω 6	0.10	0.11	0.10	0.13	0.18	0.16	0.07
18:3 ω 3	0.42	0.46	0.41	0.66	1.08	1.14	3.82
18:4 ω 3	0.48	0.53	0.49	0.46	0.41	0.39	-
20:2 ω 6	0.29	0.36	0.31	0.31	0.28	0.27	0.12
20:3 ω 6	0.17	0.12	0.17	0.15	0.11	0.10	-
20:4 ω 6	4.07	4.26	4.20	4.02	3.60	3.06	-
20:3 ω 3	0.16	0.15	0.17	0.16	0.14	0.10	-
20:4 ω 3	0.33	0.33	0.36	0.31	0.28	0.23	-
20:5 ω 3	15.65	16.20	16.19	15.31	13.75	12.09	-
21:5 ω 3	0.19	0.18	0.22	0.21	0.16	0.14	-
22:4 ω 6	0.29	0.30	0.35	0.33	0.30	0.20	-
22:5 ω 6	0.62	0.54	0.69	0.64	0.56	0.42	-
22:5 ω 3	1.64	1.55	1.73	1.62	1.42	1.21	-
Amount of polyene	48.20	49.14	50.27	51.73	52.96	48.43	55.93
Amount of ω6	6.71	6.93	6.88	10.52	15.97	15.67	52.07
Amount of ω 3	40.31	41.01	42.45	40.13	36.02	31.77	3.82

Table 2 - Relative biological value of the samples

Sample for research	Number of ciliates during the transition to the stationary phase, cells	Biological activity of the object, cells/hour	Relative biological value, %
Scalded	53 – 55	0.73 – 0.76	69 – 73
Fried in oil	48 – 50	0.67 – 0.69	63 – 66
Scalded with WB	49 – 51	0.68 – 0.71	65 – 68
Fried with WB	45 – 48	0.64 – 0.66	62 – 64
Whole cow's milk	75 – 77	1.04 – 1.07	100