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IMPROVING THE TECHNOLOGY OF PROCESSING OIL FLAX SEEDS FOR THE PRODUCTION OF FUNCTIONAL FAT-AND-FLOUR PRODUCTS

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Abstract

One of the main problems of modernity is the sharp increase in alimentary-dependent diseases, or so-called "diseases of civilization," caused by unbalanced nutrition, namely a stable deficiency or excessive intake of nutrients with food relative to human physiological needs. Therefore, there has recently been increased interest in the production of functional foods with a relatively balanced composition of certain nutrients, depending on their purpose and intended use. A promising object of modification is traditional fat products, the transformation of which into functional products is carried out, including by combining various types of raw materials, that is, creating composite (model) mixtures. The aim of the research was to develop a waste-free technology for producing edible flaxseed oil and functional fat-and-flour products (composite mixtures) by combining various types of fat components and flour from flaxseed cake. Traditional methods for oil extraction plant laboratories were used. The optimal ratios of various types of fat components and flour from flaxseed cake were determined and justified with optimization criteria for the ratio of essential polyunsaturated fatty acids of the ω6 and ω3 families of 5÷10:1 for healthy and 3÷5:1 for therapeutic nutrition. The authors consider it possible to use the resulting edible flaxseed oil and functional fat-and-flour products in the production of margarines, bakery and confectionery products.

Key words: flax, seeds, oil, cake, cake flour, fat component, combining, optimization, polyunsaturated fatty acids, fat-and-flour product, application.

Introduction

The quality of human life and its duration largely depend on nutrition. Thus, it is the stable deficiency or excessive intake of nutrients with food relative to physiological needs that causes alimentary-dependent diseases, of which about 61.0% are cardiovascular disorders, 32.0% are neoplasms (cancer), 5.0% are type II diabetes mellitus (insulin-independent), 2.0% are alimentary deficiencies (iodine and iron deficiency). Nutrition is essential in the occurrence and development of diseases of the gastrointestinal tract, liver and biliary tract, endocrine pathologies, diseases of the musculoskeletal system, and caries. These also include the so-called mass non-communicable diseases, often referred to as "diseases of civilization" and directly related to nutritional imbalances [1].

According to leading nutritionists, the population's need for essential macro- and micronutrients cannot be met by increasing the volume of consumption of traditional foods, which is fraught with obesity and, as a result, the development of concomitant diseases. Therefore, the

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production of functional foods with a relatively balanced composition of certain nutrients, depending on their purpose, is a priority direction for improving food production against the general trend towards reducing their calorie content and the volume of use of additives of non-natural (synthetic) origin, positioned as improvers of the consumer properties of these products [2, 3].

Promising objects of modification include fat products, the basic criterion of nutritional value of which is their fatty acid composition and its balance. For the transformation of a traditional fat product into a functional one, the most promising is the combination of various types of raw materials, that is, the creation of model (composite) mixtures [4, 5].

Materials and methods

The aim of the study was to develop a waste-free technology for producing edible flaxseed oil and functional fat-and-flour products (composite mixtures) by combining various types of fat components and flour from flaxseed cake.

The experimental part of the work was carried out in the laboratories of the Department of Food Technology and Service of the Bukhara Engineering Technological Institute (Bukhara, Uzbekistan).

In the work, oil flax seeds of the "Bakhmalsky-2" variety (Línum usitatíssimum L.) obtained at OOO "Zamona Rano" (Uzbekistan), meeting the requirements of GOST 10582-76 were used. Oil flax seeds. Industrial raw materials. Technical conditions.

Cold-pressed flaxseed oil and oil extracted from the cake were evaluated by acid and peroxide values, and fatty acid composition.

The acid value was determined by titrimetric method with visual indication of 0.1-30.0 mg KOH/g, described in GOST 31933-2012. Peroxide value (active oxygen content) in the range of 0.1-40.0 mmol/kg - by titrimetric method, based on the reaction of peroxides and hydroperoxides with potassium iodide in a solution of acetic acid and chloroform and subsequent quantitative determination of the released iodine with a solution of sodium thiosulfate according to the method described in GOST 26593-85. Fatty acid composition - by gas chromatographic method according to GOST 30418-96 on an Agilent 8860 GC chromatograph with a flame ionization detector with subsequent identification of fatty acids by comparing the retention times of peaks with those of the peaks of the standard sample of a mixture of 37 methyl esters of fatty acids (Supelco® 37 component FAME mix, Sigma-Aldrich, USA).

Fat-and-flour products were evaluated by organoleptic (color, taste, smell, consistency) and physico-chemical indicators (fat content, acid and peroxide values, anisidine value, content of ω6 and ω3) by acid and peroxide values, fatty acid composition, and ω6 and ω3 content.

Organoleptic (sensory) quality indicators were determined visually. Fat content of the product - by extraction-gravimetric method in a Soxhlet apparatus, based on the extraction of fat from the analyzed sample with a solvent and the determination of the mass fraction of fat after removal of the solvent, according to GOST 31902-2012. Acid and peroxide values - similarly to oil, anisidine value - by photometric method, based on the measurement of the optical density of the yellow-colored compound using a spectrophotometer, according to GOST 31756-2012 (ISO 6885:2006). The quantity and ratio of PUFA ω6 and ω3 are calculated by calculation method.

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Results and discussion

It is known that throughout the world, flaxseed oil is now obtained only by a single cold pressing under mild, gentle pressing conditions at a temperature not exceeding 50±1.00C. The resulting cake is usually used to obtain technical oil by repeated pressing in a relatively harsh mode or by extraction.

The classic method of processing oil flax seeds (OFS) is their double hot pressing and extraction of the cake with organic solvents. Before each pressing, a rather long (about 40 minutes) hydrothermal treatment of the pulp at high temperatures (110÷130ºC) is provided to obtain the pulp before the first stage and the cake - before the second stage of pressing. The oil obtained after the first pressing using this technology is inferior in nutritional value and functional properties to cold-pressed oil. In addition, the oil from the second pressing is technical, that is, unsuitable for food mainly due to safety (oxidative damage). The resulting meal is also suitable only for animal feed.

A method has been developed for producing a food fat-and-flour product with a balanced ratio of ω6 and ω3 fatty acids, comprising mixing fat and flour components. As the fat component, solid and plastic anhydrous culinary or unesterified fats, or palm oil, are used, without the addition of any liquid vegetable oils, and as the functional flour component, freshly prepared un-defatted flaxseed mass is used [15-18].

At the same time, due to the large variability of the fatty acid composition of the used fat components and the oil content of OFS, the ratio of components is determined by solving the corresponding system of equations. 1, 2:

$$\boldsymbol{M_j = M_l\,(C_l^{\omega6} - C_l^{\omega3}.\,y) / ((M_l\,(C_l^{\omega6} - C_l^{\omega3}.\,y) - 100(C_j^{\omega6} - C_j^{\omega3}.\,y))} \qquad (1)$$

$$\boldsymbol{m_{l.m} = 1 - m_j} \qquad (2)$$

where: $\boldsymbol{m_j}$ – mass of non-defatted flaxseed mass, kg; $\boldsymbol{m_{l.m.}}$ – mass of non-defatted flaxseed mass, kg;; $\boldsymbol{M_l}$ – oil content (oiliness) of non-defatted flaxseed mass, %; $\boldsymbol{C_l^{\omega6}}$ – "content of linoleic acid in the oil contained within the non-defatted flaxseed mass, %;"$\boldsymbol{C_l^{\omega3}}$ – "content of linolenic acid in the oil contained within the non-defatted flaxseed mass, %;"$\boldsymbol{C_j^{\omega6}}$ – "content of linoleic acid in the fat component, %;"$\boldsymbol{C_j^{\omega3}}$ – "x – the content of linolenic acid in the fat component, %; y – the required ratio of PUFAs ω6:ω3 in the fat and flour product."

In this method, a fat component preheated to 1050C (up to 1200C is allowed) for 10 minutes is used, and the flaxseed mass is obtained both from pre-treated and untreated OFS.

This method allows 100% use of the botanical content of oil and other physiologically useful nutrients (proteins, carbohydrates, dietary fiber, etc.) of the seeds, however, it does not provide for the preliminary extraction of valuable high-quality flaxseed oil of the first cold pressing. In addition, the process of mixing the components in the specified mode may cause an increase in the peroxide and anisidine values of the fat-and-flour product.

The solution to the above problems is possible when using air separation of whole seeds (total impurity no more than 2.0%) to a moisture content of no more than 8.0±1.0% at the first

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stage, then extracting high-quality edible oil with a high content (up to ~56.0%) of essential α-linolenic (ω3) acid, by cold pressing in gentle pressing modes. However, the oil yield is quite low (about 26.0÷30.0%), and the residual oil content of the cake is quite high (about 18.0÷20.0%). Existing technologies provide for repeated pressing, involving grinding and hydrothermal treatment of the first pressing cake at a temperature of 110÷120ºC for 40 minutes with subsequent final pressing of the oil on a press-expeller, which allows to increase the oil yield, reducing the oil content of the cake to 8.0±9.0%. However, the oil from the second pressing using the existing hot pressing technology is obtained technical, and not edible. In this regard, this method aims not to increase the yield of flaxseed oil, but to maximize the use of the botanical oil content of flax seeds as a whole for food purposes to obtain high-quality oil and a functional fat-and-flour product. Therefore, at the second stage, the obtained cake with a significant content of residual oil (18.0÷20.0%) is ground into flour and mixed for 20÷30 seconds with a certain fat component, preheated to a temperature of 1400C, then the mixture is cooled. Heat treatment at 1400C of the cake ground into flour contributes to its unique sterilization and better preservation. In the resulting edible functional fat-and-flour product (FFP), anhydrous fats and their mixtures are used in ratios that provide a plastic-solid or ointment-like consistency.

It should be noted that the content of linolenic (ω3) acid in the oil contained in the flaxseed cake is higher compared to the flaxseed oil itself, cold-pressed from flax seeds with an oil content of 44.0% (Table 1).

"Table 1. Main indicators of cold-pressed flaxseed oil and residual oil extracted from flaxseed cake (residual oil content 19.0±1.0)"%)

(Name of Indicators/Parameters)	Values of flaxseed oil quality indicators	
	cold-pressed	extracted from the oil cake after cold pressing
Acid value, mg KOH/g)	1,13±0,04	1,25±0,03
(Peroxide value, mmol active oxygen/kg)	1,44±0,05	1,71±0,05
(Fatty acid content, %:)		
(stearic)	1,9	1,3
(palmitic)	4,7	2,6
(palmitoleic)	0,1	0,07
(oleic)	20,5	10,4
(linoleic (ω6))	22,1	7,4
(linolenic (ω3)))	49,7	77,4
(arachidic)	0,2	0,05

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(other)	0,8	0,78
ω3 (ω6 : ω3 ratio)	***1,0 : 2,2***	***1,0 : 10,5***

This is probably due to the stronger binding of unsaturated fatty acids to the cellular protein components of flax seeds. The relatively high content of linolenic acid in the oil extracted from flaxseed cake than in the oil extracted from flax seeds contributes to a relatively low dosage of ground cake in fat-and-flour compositions to achieve the necessary balance of fatty acids ω6 and ω3.

At the same time, the ratios of flaxseed cake (i.e., cake flour) and the fat component are selected in such a way as to obtain a functional food fat-and-flour product with a balanced ratio of PUFA fatty acids ω6 and ω3. The ratios of components of such a fat-and-flour mixture are calculated similarly using equations 1 and 2, with the only difference being that the values of the main parameters of the equations are taken not for the flaxseed mass, but for its cake

The method excludes the processes of secondary pressing of the cake and its extraction with any solvent.

Let's consider examples of obtaining FFP with different compositions and variability of the main ingredients.

Example 1. Using palm oil as a fat component.

FFP for prophylactic purposes with a PUFA ratio ω6:ω3 = 10:1 (y = 10) contains the following ingredients:

Palm oil (fat component) 93.0%

Flour from flaxseed cake 7.0%

The feasibility of combining these raw materials is due to the fact that palm oil contains ~10.0% linoleic (ω6) acid, and linolenic (ω3) is not detected. The mass fraction of fats in the product is on average 94.3% and its use is recommended as an alternative to margarines in the production of bakery and confectionery products in order to fortify their functional properties and reduce cost.

With the required PUFA ratio ω6:ω3 in FFP 3÷5:1 (y = 3÷5), the calculated ratio of ingredients is:

Palm oil (fat component) 79.0÷86.0%

Flour from flaxseed cake 21.0÷14.0%

At the same time, the fat content of this functional product can vary from 82.9 to 88.6% (depending on the value of y), it is recommended for use in the recipe of low-fat margarine products with a balanced fatty acid composition.

Example 2. Using interesterified cottonseed palmitin as a fat component.

FFP with a PUFA ratio ω6:ω3 = 10:1 (y = 10) contains the following ingredients:

Interesterified cottonseed palmitin 73.0%

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Flour from flaxseed cake 27.0%

It should be noted that the interesterified cottonseed palmitin contains ~47.0% linoleic (ω6) acid, and linolenic (ω3), as in the case of palm oil, is not detected.

The fat content in such an anhydrous ointment-like product is on average 77.9% and is recommended in the production of bakery and confectionery products.

Example 3. Using interesterified fat grade 1 as a fat component.

FFP with a PUFA ratio ω6:ω3 = 5:1 (y = 3÷5) contains the following ingredients:

Interesterified fat grade 1 53.0÷66.0%

Flour from flaxseed cake 47.0÷34.0%

In interesterified fat grade 1, the content of linoleic (ω6) acid is on average 35.4%, and linolenic (ω3) is 0.4%. Recommended in the production of functional low-fat margarine products.

Example 4. Using culinary fat as a fat component.

FFP with a PUFA ratio ω6:ω3 = 10:1 (y = 10) contains the following ingredients:

Culinary fat 91.0%

Flour from flaxseed cake 9.0%

In the case when the required PUFA ratio ω6:ω3 in the fat-and-flour product is 3÷5:1 (y = 3÷5), the components are selected in the following ratio in accordance with the calculation:

Culinary fat 84.0÷75.0%

Flour from flaxseed cake 16.0÷25.0%

Such fat-and-flour compositions, with a fat content of 80.1 to 92.8%, can be successfully used in cooking.

Example 5. Using confectionery fat as the fat component.

FFP with a PUFA ratio ω6:ω3 = 10:1 (y = 10) contains the following ingredients:

Confectionery fat 75.0%

Flour from flaxseed cake 25.0%

The content of linoleic (ω6) acid in confectionery fat averages 40.0%, and linolenic (ω3) - traces. The fat content in such a product averages 79.6%, recommended in the production of flour confectionery products.

Organoleptic and physico-chemical quality indicators of fat-and-flour products with minimum (min) and maximum (max) content of flour components are shown in Table 2.

"Table 2. Main organoleptic and physico-chemical quality indicators of fat-and-flour products"

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Indicators	Values of fat-and-flour product indicators			
	According to the prototype, with the addition of full-fat mass of ground flax seeds, in the amount of:		Proposed, with the addition of ground flaxseed cake, in the amount of:	
	7% (min)	*39% (max)*	*7% (min, according to example 1))*	*47% (max, according to example 3)*
Color	Creamy or light brown	Brown	Creamy or light brown	Brown
Taste	Characteristic of deodorized fat	With a slightly floury taste	Typical of deodorized fat	With a slightly floury taste
Smell/Odor	Typical of deodorized fat	Characteristic of this type of product	Typical of deodorized fat	Characteristic of this type of product
Consistency	Homogeneous, without lumps, oily.			
Fat content, %	95,5	77,8	94,3	62,4
Acid value of extracted fat, mg KOH/g	0,2	0,32	0,2	0,33
Peroxide value of extracted fat, mmol active oxygen/kg	2,1	2,5	1,28	1,57
Anisidine value, units	2,97	3,45	2,63	2,98
PUFA ω6:ω3 ratio	10 : 1	3 : 1	10 : 1	3 : 1
Increase in QMAFAnM (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms) over 90 days, CFU/g	155	185	142	163

It has been established that increasing the concentration of fat in FFP by adding anhydrous fat components and the relatively high processing temperature during mixing contribute to better preservation of fat-and-flour products. In the FFP samples presented in Table 2, only after 90 days of incubation and only in samples with the maximum content of flaxseed flour, insignif-

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icant amounts of yeast and mold fungi were found (0.2±0.1 CFU/g). Escherichia coli bacteria were not detected.

Thus, it was established that according to the results of microbiological screening, the studied FFPs meet the requirements of San PiN 0138-03 in the prolonged storage period by the manufacturer of this product.

The obtained experimental data allow us to conclude that obtaining valuable edible oil from flax seeds and functional FFPs with flour from flaxseed cake using the proposed method is technologically and economically very effective.

Conclusion. Thus, the method of obtaining high-quality edible flaxseed oil from air-separated cleaned seeds without preliminary processing by cold pressing in mild pressing modes (pressing temperature no more than 50ºC), characterized in that the cake obtained in the process with a significant content of residual oil (18.0÷20.0%), rich in PUFAs of the ω3 family, is dispersed and used as a flour component for obtaining a functional food fat-and-flour product. As a fat component, anhydrous culinary, interesterified fats (based on animal fats or salomas), as well as vegetable oils characterized by oxidative stability (sunflower, sesame, cottonseed, palm oil, etc.), having sufficient structural consistency (hardness) at room temperature, can be used.

This ensures the implementation of priority directions of the state's development strategy in the field of healthy nutrition of the population, the economic component in terms of reducing the cost of production by creating a waste-free technology for the complex processing of plant raw materials. Combining natural raw materials with certain pronounced functional properties allows to increase the level of nutritional value and safety of food products.

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