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Creation of Innovative Solutions for the Production of Composite Vegetable Oils Balanced in Fatty Acid Composition

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***Abstract*—Modern nutrition science focuses on the creation of innovative technologies and increase the assortment of finished products with directional changes in chemical composition and properties with a view to implementation in the food industry.**

The problem of imbalance of PUFA in a diet of people is investigated. It is proposed to use perspective vegetable sources of oilseeds. Considered the composition and properties of products of processing of vegetable materials of the Russian, which includes ω-3 PUFA. On this basis, the prospects for the use of PUFA in food production are determined. The formulations of fat products with the necessary structural-rheological and physic-chemical parameters that are balanced by the ratio of saturated, monounsaturated and polyunsaturated fatty acids are designed.

Keywords—food safety, composition, blending, vegetable oil, PUFA balance

I. Introduction

The " Doctrine of food security of the Russian Federation "(№120 of January 30, 2010) and" Fundamentals of the policy of the Russian Federation in the field of healthy nutrition for the period up to 2020 " (№1873-R of October 25, 2010) refers to priority policy directions related to healthy nutrition in the Russian Federation. These directions should preserve and strengthen the health of the population; to ensure the prevention of illness that are caused by inferiority and imbalance of nutrition; to expand the production of the main range of food raw materials, etc. Food safety is the food independence of the country, which helps to fight against external threats, which removes pressure on the country, creates conditions for stable food supplies to the population in the event of an economic blockade. To ensure food safety, Russia needs to increase its own food production [1-3]. One of the main problems that affects the safety of products is the state of the environment. As a result of the active impact of civilization on the environment, the degree of its pollution leads to an increase in the level of food pollution from the external environment. Therefore, sanitary and hygienic aspects in food production are given special importance.

In our country, the caloric content of the daily diet of the population in recent years does not exceed 2700 kcal, and according to FAO recommendations should be 3000 kcal per day. Thus, the directions of development of new technologies predetermine the optimization of the composition and properties to create products that correspond to the formula of a balanced diet [4, 5]. Priority research and practical developments study how to plan the composition of foods and diets, taking into account the balance of fatty acid, amino acid, mineral and vitamin composition [6, 7].

In the clauses of the basic provisions, which refers to the design of the structure of products that are balanced by the main indicators, the accent is on the purposeful change of the fatty acid composition of the lipid fraction for its maximum approximation to the best ratio of polyunsaturated, monounsaturated and saturated fatty acids. They must conform to physiological norms.

Modification of the composition of oils is caused by discrepancy of known edible oils with modern requirements for ideal fat. A balanced fatty acid composition have not natural fats and oils, that is in the diet of the person is not present the optimal ratio of saturated, mono and polyunsaturated fatty acids, and also acids forming kind ω-6 and ω-3 and monounsaturated fatty acids kind ω-9. In refined oils, the content of phytosterols, vitamin E, phospholipids, carotenoids and other physiologically valuable compounds is insufficient, although their taste advantages and high consumer characteristics are undeniable. Unrefined oils have micronutrients in their composition, but contain undesirable concomitant substances that reduce their nutritional value or make it difficult to use in food technologies.

Now there is enough information on the effect of polyunsaturated fatty acids (PUFA) on the human body. Cellular and molecular mechanisms of their curative and preventive action were determined [8]. The beneficial effects of PUFA on the body and help with atherosclerosis, coronary heart pathology, arterial hypertension, type 2 diabetes, obesity, chronic inflammatory diseases, neurodegenerative diseases, eye diseases, some oncological diseases have been proven [9-12].

The content of polyunsaturated fatty acids in the composition is a big deal in assessing the quality of oilseeds. Linoleic and linolenic acids are the most significant representatives of the kind of polyunsaturated fatty acids (PUFA) in vegetable oils. They are derived by virtue of the biosynthesis of plant organisms, shaped from oleic acid.

Institute of nutrition Russian Academy of medical Sciences provides the following information: about 80 % of Russians lack these acids. Because of this, coronary thrombosis develops - fats, which contain a lot of saturated fatty acids, increase blood clotting [13]. In humans, the physiological role of PUFA depends on their metabolites. Recent studies have shown that PUFA of the ω-3 kind are involved in normalizing fat metabolism, increasing the plasticity of blood vessels, reducing blood viscosity, and activating immunity [14]. At the present stage, the main violation in human nutrition is a deficit of PUFA [15].

Polyunsaturated fatty acids (linoleic C18:2 (ω-6), linolenic C18:3 (ω-3), arachidonic C20:4 (ω-6)) is an important essential factor of nutrition: the body can't produce them and so they come only with food. The biological properties of acids confirm that they are vital substances (referred to as vitamin B).

Development of composite products, balanced in fatty acid composition, with maximum hygienic purity, absence of harmful impurities, chemical compounds, GMOs and possible full preservation of their nutritional and biological value. Blend vegetable oils is an effective technological method in order to achieve a given ratio of fatty acids of different types, creating two-or multi-component mixtures of natural vegetable oils enriched with biologically active components and fat-soluble vitamins, in consequence of this having increased oxistability due to the changed fatty acid composition and isomeric composition of tocopherols [16].

II. Experimental

The object of research were non-traditional oils (Fig. 1) that profitably allow to obtain specific fatty acids and other lipids that are not found in traditional vegetable oils, or are present there in small quantities: corn oil (GOST 8808-2000), amaranth oil (Technical Conditions U 15.4-32448339-001:2007) and linseed oil (GOST 5791-81). In the course of the research, the accent was placed on the study of organoleptic, physical and chemical properties, and safety

Fig. 1. Vegetable oil: а) amaranth oil; б) corn oil;в) linseed oil; г) composite oil.

indicators of the original vegetable oils as components for the created composition. To assess the quality of vegetable oils, GOSTs and methods listed below were used.

According to GOST 11812-66 evaluated the color, smell, transparency and the proportion of phosphorus material. Qualitative test for soap was carried out according to standard methods GOST 5480-59. Moisture and volatile matter were determined-. The amount of peroxide value was determined in vegetable oils titrimetric method GOST R 51487-99. Acid number-found by titration of a fat sample with potassium hydroxide solution. As an indicator used phenolphthalein (GOST R 52110-2003). Using the Lovibond PFX 995 device, chromaticity was determined according to GOST 5477 - 93. The measurement range is from 420 to 710 nm and the result was obtained in iodine units and the Lovibond color scale RYBN (red, blue, yellow, neutral). Iodine number in the samples was determined according to GOST 5475-69; the content of soap samples according to GOST 5480-59. The mass fraction of tocopherols was determined by MU 08-47/184 (FR. 1.31.2005.01810) by HPLC.

With the help of a modified technique, the composition of fatty acids of oils was found on a gas chromatograph "Chromatek-Crystal". Flame ionization detector was used in the research. Sample preparation and determination of fatty acid composition was carried out according to GOST 51483-99. Amino acid composition was determined by ion exchange chromatography using AAA-881 amino analyzer.

Determination of toxic elements was carried out according to GOST 30538-97, the presence of radionuclides was tested according to GOST 32163-2013 (strontium) and GOST 32161-2013 (cesium-137). The content of dioxins was found on the Methodical Instructions M3 Russian Federation from 01.06.99 by chromatography-mass spectrometry. Determination of mycotoxins was carried out according to GOST 30711-2001 and GOST 15891-2013.

During the experiments, we used the method of optimizing the composition and properties of the composition of vegetable oils, which have different fatty acid composition by blending. A study was conducted of the chemical composition and physico-chemical properties of edible fats and liposonix composite products. The possibility of using non-traditional oils in the production of functional fat compositions, taking into account the formula of balance of fatty acid composition. The method is available and convenient for use in production conditions.

According to the Institute of nutrition RAMS the best ratio of PUFA ω-6: ω-3 in the diet of a healthy person (9...10):1. With their simultaneous entry into the human body, competitive mutual relations in the metabolism of these acids are manifested, and this influences the synthesis of arachidonic acid. In the pathology of lipid metabolism, the recommended ratio ω-6: ω-3-5: 1 and even 3: 1. Analysis of the results of monitoring the actual nutrition of the population showed that these polyunsaturated fatty acids enter the body in a ratio of 10: 1 to 30: 1. Therefore, we have a constant shortage of PUFA family ω-3.

The method of linear programming was used to obtain compositions of vegetable oils [17].

A three - component composition of vegetable oils-corn, linseed and amaranth-was considered. At the first stage, the ratio of two main components - corn and linseed oils-was determined. At the second stage, the proportion of the third component - amaranth oil was found. It was injected to improve physical and chemical performance.

First stage. We calculate the mass fraction of vegetable oils in the preparation of a two-component composition:

$$\begin{cases} \dfrac{m_n \cdot c_n^1 + m_p \cdot \tilde{n}_p^1}{m_n \cdot c_n^2 + m_p \cdot \tilde{n}_p^2} = 5 & (1) \\ m_п + m_р = 1, & (2) \end{cases}$$

where $m_п$ -the amount of corn oil; $m_р$ -the amount of linseed oil, t; $c_п^1$ -the concentration of linoleic acid in corn oil, wt.% ; $c_п^2$ -concentration of linolenic acid in corn oil, wt.% ; $c_р^1$ -con-centration of linoleic acid in linseed oil, wt.% ; $c_р^2$ -concentration of linolenic acid in linseed oil, wt.%.

The system of equations (1) and (2) was solved with respect to the values of $m_п$ and $m_р$. Further, in the calculations, the prepared two-component composition is considered as a homogeneous vegetable oil with constants: $c_{см}^1 = (m_п x c_п^1 + m_р x c_р^1)$ - concentration of linoleic acid in two-component oil composition, wt.%; $c_{см}^2 = (m_п x c_п^2) + m_р x c_р^2$ - concentration of linolenic acid in two-component oil composition, wt.% , where $m_{см}$ is the mass of the composite two-component oil.

Second stage. We calculate the mass fraction of the composite two-component oil and the third component of amaranth oil in the preparation of a three-component composition:

$$\begin{cases} \dfrac{m_{cm} \cdot c_{cm}^1 + m_c \cdot \tilde{n}_c^1}{m_{cm} \cdot c_{cm}^2 + m_c \cdot \tilde{n}_c^2} = 5 & (3) \\ m_{см} + m_с = 1, & (4) \end{cases}$$

where $m_с$ -the amount of amaranth oil, t; $c_с^1$ -the concentration of linoleic acid in amaranth oil, wt.% ; $c_с^2$ - concentration of linolenic acid in amaranth oil, wt.%;

The system of equations (3) and (4) was solved with respect to the values $m_{см}$ and $m_с$.

Solving these equations, we obtain that when mixing vegetable oils in the ratio of corn oil -59.24 %, linseed oil - 23.29 % and amaranth oil -17.47 %, we achieve all the required ratios of acids ω-6: ω-3 (5:1).

III. RESULTS AND DISCUSSION

During the work we used generally accepted and original research methods. Experiments were carried out 3-4 times and processed by statistical methods. In the experimental part, the average values of the indicators are given.

According to the standard methods in the Center of collective use "Control and management of energy efficient projects" of the Federal state budgetary educational institution of higher education “VSUET” and production laboratory "Deko minerals", a study conducted organoleptic and physico-chemical characteristics not refined source of vegetable oils and compositions as well as safety indicators, characterizing hygienic requirements and quality of the product. The results of studies of the characteristics of the biochemical composition of the starting oils and the composition are presented in table I-III.

Of organoleptic and physico-chemical parameters shows that the initial oil cold pressed, meet the requirements of TR CU 024/ 2011 "Technical regulations on fat and oil products" dated 09.12.2011. They can be used in food excluding additional processing (refining, deodorization).

In the development of high-quality compositions of vegetable oils, the composition of fatty acids, promising from the point of view of preserving the native properties of oils, as well as to identify their resistance to oxidation, was studied.

The results of researches of fatty acid composition of oils are shown in table IV.

One of the most significant groups of pollutants of vegetable oils are toxic elements that have a large spectrum of negative effects and provide of great danger when exposed to constant even in small doses.

Toxic effect can have even metals that are necessary for human life (copper, iron), if they are in the body in excess of the required amount for metabolism. The content of toxic elements, mycotoxins, pesticides, radionuclides, as well asmicrobiological indicators for the oil should not exceed the levels normalized by SanPiN 2.3.2 1078-01 "Hygienic requirements for safety and nutritional value of food products". Hence, it became necessary to determine the content of toxic elements in the source oils and the composition of table V, VI.

TABLE I. ORGANOLEPTIC QUALITY INDICATORS OF THE INITIAL OILS AND COMPOSITIONS

Indicator name	Corn oil	Linseed oil	Amaranth oil	Composition of vegetable oils
Smell and taste	Smell and taste corresponds to corn oil without external smells and taste	The smell is characteristic sugary and taste corresponds to linseed oil without external taste and bitterness	Smell and taste corresponds to amaranth oil without external smells and taste	A specific smell characteristic of oils. It has a spicy, slightly tangy taste
Color	Yellow of different intensity	Light brown	Yellow of different intensity	Dark gold
Transparency	Oil over the sludge after settling should be transparent	Oil over the sludge after settling should be transparent	Oil over the sludge after settling should be transparent	Transparent

TABLE II. CHARACTERISTICS OF THE BIOCHEMICAL COMPOSITION OF VEGETABLE OILS

Name of indicators	Value of indicator		
	corn oil	*amaranth oil*	*linen oil*
Degree of transparency, FEM	1,0	1,0	1,0
Tocopherols, mg / kg	665	2550	225
Peroxide value, mmol of active oxygen kg	2,50	3,35	2,31
Mass fraction of moisture and volatiles, %	0,01	0,01	0,01
Acid value, mg KOH / g	2,31	3,40	1,95
Color number, mg J	67,0	61,0	43,0
Soap (quality test)	not normalized	not normalized	not normalized
Mass fraction of phosphoprous-containing matter, % in calculation on stearooleocytin	0,02	0,02	0,02
Compound with conjugated double bonds, l/g. cm: dienes trienes	 0,50 0,14	 0,30 0,15	 0,21 0,02

TABLE III. CHARACTERISTICS OF THE BIOCHEMICAL STRUCTURE OF THE OIL COMPOSITION

Indicator	Content
Acid value, mg KOH/g	1,11
Peroxide value, mmol of active oxygen, kg	2,76
Iodine number, g J2/100g	112
Mass fraction of waxes, %	0,15
Color number, mg J2	28,1
Mass fraction of moisture and volatiles, %	0,05
Mass fraction of unsaponifiable substances, %	0,21
Saponification number, mg KOH/g	172
Mass fraction of tocopherols, mg/kg:	
α-tocopherol	438,4
β-tocopherol	217,2
γ-tocopherol	303,3

TABLE IV. FATTY ACID STRUCTURE OF OILS

Fatty acid composition, % to the sum of fatty acids	Corn oil	Amaranth oil	Linseed oil	Composition
Linoleic	1,2	50,0	15,6	47,10
Arachidic	0,4	0,16	0,1	1,59
Palmitic	2,8	19,1	5,8	7,11
Oleic	53,8	22,62	20,1	23,58
Linolenic	0,6	1,0	53,4	4,67
Gondoinic	0,3	0,20	0,1	8,27
Stearic	31,3	1,31	4,3	2,26
Begenova	0,3	0,05	0,1	0,20

TABLE V. CONTENT OF HARMFUL SUBSTANCES IN SOURCE VEGETABLE OILS

Indicator	Content in mg/kg		
	corn oil	*amaranth oil*	*linseed oil*
Toxic elements, mg/kg:			
plumbum	0,027	0,020	0,027
copper	0,15	0,17	0,17
arsenic	0,041	less 0,04	less 0,04
mercury	0,008	0,007	0,007
cadmium	0,0035	0,0030	0,0034
ferrum	2,50	2,25	2,30
HCH and isomers, mg/kg, max	0,20	0,20	0,20
DDT and its metabolites, mg/kg, no more than	0,20	0,20	0,20
Mycotoxins, mg/kg: aflatoxin B1 no more	 0,004	 0,004	 0,004
Radionuclides, BK/kg(l): cesium-137 strontium-90	Not detected	Not detected	Not detected
Pesticides: hexachlorocyclohexane (alpha-, beta-, gamma- isomers)	Less 0,01	less 0,01	less 0,01
Dioxins, mg/kg	Less than detection limit	Less than detection limit	Less than detection limit

TABLE VI. CONTENT OF HARMFUL SUBSTANCES IN THE COMPOSITION OF VEGETABLE OILS

Indicator	Content in the composition, mg/kg	Allowable level, mg/kg
Toxic elements		
plumbum	0,021	0,1
mercury	0,007	0,03
ferrum	2,20	5,0
arsenic	<0,01	0,1
copper	0,15	0,4
cadmium	0,0032	0,05
Radionuclides, BK/kg(l) Cesium-137 Strontium-90	Not detected	 200 100
Mycotoxins		
DDT and its metabolites	-	0,2
Pesticides: hexachlorocyclohexane (alpha-, beta-, gamma- isomers)	<0,01	0,2
Aflatoxin B1	-	0,005

It should be noted that the presence in oils and vegetable oils composition of a small amount of heavy metal salts, acting as prooxidants, can accelerate their oxidative damage, as long-term storage of vegetable oils can transition metals from the packaging material. Therefore, we investigated the storage capacity for 8.5 months in glass and iron containers. A direct correlation discovered between the content of free fatty acids in oils (total number) and an increase in the concentration of iron during the storage period at 18-22 ^{0}C in laboratory tanks with a capacity of 250 sм^{3} table VII.

Free fatty acids of the initial oils and compositions, interacting with the metal of the inner surface of the tank, formed a certain amount of fatty acid salts of iron, which were active catalysts for oxidation of the oil. In the composition of oils was noted the process associated with the suppression of oxidative reactions due to the content of natural antioxidants (tocopherols).

After analyzing the results, multicomponent composite oils structure were designed, the composition of which meets hygienic, biomedical requirements. The permissible level of harmful substances in the normal content of saturated acids in the composition of vegetable oils from 26 to 39 %. The amount of saturated acids in the composition of vegetable oils - from 26 to 39 %. Saturated fatty acids with an average carbon chain length, caprylic C8:0 , lauric C12:0, caprinic C10:2 and myristic C14:0 are present in oils in an amount of 8 to 16 %. When the content of monounsaturated fatty acids changes-30 %, the resistance of the fat phase to oxidation increases [12].

The developed compositions contain from 10 to 15 % of polyunsaturated fatty acids, and this corresponds to the formula of "hypothetically ideal fat". Omega-3: omega-6 fatty acids have a 1:5 ratio. It fits medically normal. Implementation of the principle of balance in the ratio between saturated, monounsaturated and polyunsaturated fatty acids allowed to design the formulation of fat products with the necessary structural- rheological and physico-chemical properties.

IV. Conclusion

It was established that the physico-chemical parameters of all oils meet the requirements for edible oils (TR CU 024 / 2011 "Technical regulations for oil and fat products"), on safety indicators - the requirements of TR CU 021/2011"Technical regulations on food safety".

TABLE VII. MASS FRACTION OF IRON AND PEROXIDES (P. H.) IN OILS AND COMPOSITIONS WHEN STORED FOR 8.5 MONTHS

Oil	**Iron content, mg/kg**	
	in glass containers	***in an iron container***
Corn	2,50	3,01
Linen	2,30	2,91
Amaranth	2,25	2,63
Composition	2,20	2,48

Having a set of studies on this issue, we can say that the resulting composition of vegetable oils with a ratio of polyunsaturated fatty acids ω-3 and ω-6 1:5 has a high nutritional and energy value, the best consumer properties, high functionality and therapeutic and preventive action. The effect of the use of composite oils is better than the oils separately. This could be a prospect for research and development directed at providing a healthy diet.

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