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Blends of unrefined vegetable oils for functional nutrition

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Abstract. The unbalanced ratio of ω-3/ω-6 of polyunsaturated fatty acids (PUFAs) causes a number of alimentary-dependent diseases, and the intake of capsulated forms as biologically active additives does not always take into account the established eating behavior of the population and the hedonic aspect of food consumption in general.
The Saratov region is one of the leading agricultural regions in the Russian Federation, one of the leaders in the cultivation and processing of low-used but valuable oily raw material, such as seeds of mustard, milkthistle, camelina, safflower.
The object of the study were the above listed oils and their food compositions obtained by blending. The functionality and biological efficiency of the initial oils were investigated by gas-liquid chromatography. Applying the methods of mathematical modeling, new food systems with the specified characteristics were designed (achieving the optimal ratio of ω-3: ω-6 acids). The most promising samples were selected through sensory analysis. Functional and sensory properties were taken as reference points for selection. The developed mathematical model is applicable to this food system, which was proved by the study conducted empirically. As a result of the work performed, blends of elite unrefined vegetable oils with health-promoting properties were obtained; their use in nutrition is designed to contribute to the formation of a healthy and active longevity in general, as well as to the minimizing the deficit of essential factors of nutrition in the child's body, athletes in the popular sports and sports of records.

Key words: blends of unrefined vegetable oils, sources of polyunsaturated fatty acids, safflower oil, camelina oil, milkthistle oil.

INTRODUCTION

Edible fats are the necessary part of human diet, making up about one third of its total calorie content, they occupy the second place in solving the world food problem and are the most important factor in the food security of any country (Teesalu, 2006; Lenihan-Geels et al., 2013; Zaytseva & Nechaev, 2014; Sanguansri et al., 2015; Pitsi et al., 2017). The consumption of fats in the diet of contemporary man has increased dramatically, mainly in the latent form.

Studies of late years, which revealed the role of lipids in humans and animals, allowed evaluating and specifying the effect of these substances on the metabolic processes at all levels of the organization of living matter. Fats are characterized by a wide range of functions due to the high diversity of their structures, although initially they were considered only as a powerful source of energy. In addition, lipids are the part of the information framework of the body, they form and organize information flows and fill them, providing active interaction with the environment. Disorders in the lipid system of the body are observed at different pathological disturbances. A while ago it became known that essential fatty acids enhance the protective functions of the body (Filipovic et al., 2016; Grant & Guest, 2016; Andrieu et al., 2017; Arnold et al., 2017). Their role in the regulation of signal information is great. PUFAs are able to interact with ion channels, thereby initiating a rapid response of the cell to the information received. Due to the peculiarities of its structure, PUFAs can undergo oxidative transformations of the carbon skeleton with the formation of several hundreds biologically highly active metabolites, united by the common term ‘oxylipins‘ (Arnold et al., 2017; De Oliveira et al., 2017; Kerdiles et al., 2017; Okonenko & Shakhabutdinova, 2017; Saini & Keum, 2018; Mazahery et al., 2019). The two main groups of PUFAs are the acids of the ω-6 group and ω-3 group; ω-6 acids are found in almost all vegetable oils. The body's need for polyunsaturated fatty acids is not permanent, it may vary depending on age, nature of labor activity, living conditions, in particular climatic conditions, health condition and other factors.

Recommendations on the fatty acid composition of edible fats for the nutrition of a healthy body, approved by the Research Institute of Nutrition of the Russian Academy of Medical Sciences, are given in Table 1.

Table 1. Composition of fat products for healthy human nutrition

Degree of unsaturation of fatty acids	The ratio of fatty acids, in % from total calorie value of the daily diet
Saturated	Not more than 10
Monounsaturated	10
Polyunsaturated	From 6 to 10
The ratio of polyunsaturated acids ω6/ω3	From 5 to 15

These standard rates for the total consumption of polyunsaturated fatty acids are close to the recommendations of FAO/WHO, but significantly lower than the level of consumption of ω-3 acids recommended by the International Society of Nutrigenetics/Nutrigenomics (Zaytseva & Nechaev, 2014). Instructional guidelines of Rospotrebnadzor of the Russian Federation (Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing of the Russian Federation) determine the optimal ratio in the daily diet of ω-6:ω-3 fatty acids as 5–10:1 (Tutelyan, et al., 2009). Each fat taken separately (from used in food) both vegetable, and animal origin does not fully meet all those requirements which are imposed to edible fat now. Therefore, to create complete diets, it is necessary to use fats and oils in certain combinations that are favorable for the human body (O'Brien, 2008).

The Saratov region is one of the leading agricultural regions in the Russian Federation, one of the leaders in the cultivation and processing of low-used but valuable oily raw material, such as seeds of mustard, milkthistle, camelina, safflower. These types of oils, unfortunately, have not yet found wide application in food industry.

The presented types of oils have functional potential determining their antitumor and bactericidal properties, stimulation of digestive, cardiovascular, endocrine and respiratory systems, improving the immune status of the body (Zilmer, et al., 2010; Obukhova, 2013; Aung et al., 2018).

The aim of this work was to create blends of these unrefined vegetable oils obtained by cold pressing, balanced by ω-3/ω-6 acids from the regional raw materials of the Saratov region for functional nutrition.

MATERIALS AND METHODS

The work was performed in 2017–2018 in the Russian Federation hosted by Saratov State Vavilov Agrarian University at the Department of Food Technology in the university training and research laboratory for determining the quality of food and agricultural products.

The object of the study were:

– safflower oil, milkthistle oil, camelina oil, mustard oil. Their fatty acid composition is shown in Table 2.

– food compositions of the above listed oils in various combinations obtained by blending.

The research methods used and their brief characteristics are presented in Fig. 1.

RESULTS AND DISCUSSION

At the first stage of the research the fatty acid composition of the used oils produced from the seeds grown in the Lower and Middle Volga region was determined, it is indicated in Table 2. Method error: at the content of the desired substances: less than 5%–0.28%; equal to or more than 5%–1.42%.

Table 2. Fatty acid composition of the studied oils (averaged)

Acid name	Fatty acid composition, %			
	Camelina oil	Safflower oil	Mustard oil	Milkthistle oil
C14:0 (myristic)	0.09	0.20	0.07	0.13
C16:0 (palmitic)	5.36	7.50	3.70	9.90
C16:1 (palmitoleic)	0.09	7.20	0.16	0.11
C18:0 (stearic)	2.26	4.00	2.35	11.40
C18:1 (oleic)	14.83	21.00	43.71	25.70
C18:2 (linoleic)	17.37	75.00	32.09	34.80
C18:3 (linolenic)	37.85	0.20	11.19	2.00
C20:0 (arachidic)	1.06	0.40	0.61	6.90
C20:1 (gondoinic)	12.72	0.40	2.53	1.60
C20:2 (eicosadienoic)	1.88	1.60	0.20	2.10
C22:0 (behenic)	0.22	0.40	0.30	3.80
C22:1 (erucidic)	2.35	1.90	2.30	1.70

The imbalance of fatty acid composition of the presented vegetable oils taken separately proves the necessity of their blending. It should be noted that safflower oil is characterized by a significant content of linoleic acid isomers 18:2 with conjugated double bonds, which has anticarcinogenic activity.

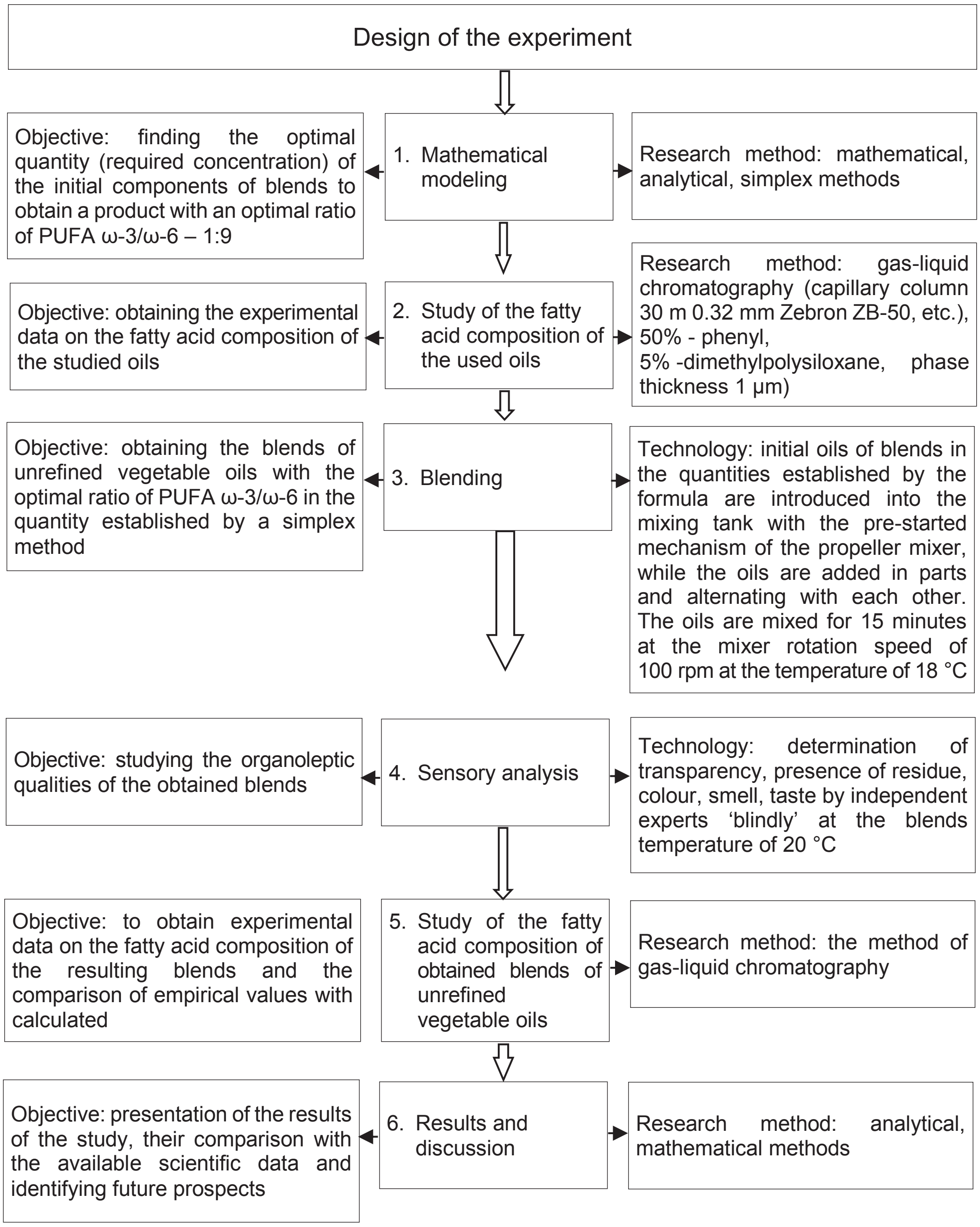

Figure 1. Design of the experiment.

Applying a simplex design of the experiment for determining the effect of fatty acid composition on the functional properties of food compositions, models of blends of unrefined oils were designed (Krasulya et al., 2015). On the basis of the obtained models, formulas of food compositions (Table 3) were proposed, the specified properties of which were confirmed experimentally (Table 4).

Table 3. Formulas, obtained as a result of simplex design

Name of oils in blends	Concentration of oils in blend, %	Design ratio of ω-6:ω-3acids
Safflower + camelina + milkthistle	50 + 13.5 + 36.5	9.94:1
Safflower + camelina + mustard	65 + 10 + 25	10:1
Safflower + milkthistle + mustard	30 + 11 + 59	9.74:1

The obtained quantitative data submit to the normal distribution. Validity of values was determined by Student's t-test, at $P < 0.05$. Statistical processing of the data was carried out according to standard methods using Microsoft Excel software package. The results given in Table 3 prove the compliance of the blends composition to the given ratio ω-6 and ω-3 fatty acids, optimal for daily consumption.

It should be noted that at present the disadvantages of the available fat composite mixtures are the unbalance ω-3/ω-6 acids, or partial destruction of nutrients under thermal influence in the process of oil manufacturing, high cost of the related initial raw material (various essential oils) for obtaining the finished product, use of oleic safflower oil. A significant disadvantage of the analyzed technologies is the use of refined oils (https://worldwide.espacenet.com; http://www.findpatent.ru).

Table 4. Average values of fatty acid composition of the designed blends

Acid name	Fatty acid composition, %		
	Blend No. 1	Blend No. 2	Blend No. 3
C14:0 (myristic)	0.1	0.2	0.1
C16:0 (palmitic)	6.2	7.4	6.9
C16:1 (palmitoleic)	0.2	0.1	0.2
C18:0 (stearic)	3.1	3.7	3.1
C18:1 (oleic)	28.7	18.0	20.5
C18:2 (linoleic)	46.5	56.3	57.2
C18:3 (linolenic)	9.9	8.2	7.7
C20:0 (arachidic)	0.7	1.1	0.6
C20:1 (gondoinic)	3.1	3.4	2.6
C20:2 (eicosadienoic)	0.4	0.4	0.3
C22:0 (behenic)	0.4	0.6	0.2
C22:1 (erucidic)	0.9	0.8	0.4

The estimated content of vitamin E equivalent (tocopherolequivalent), taking into account the whole group of tocopherol compounds (4 tocopherol and 4 tocotrienol) united by the common term ʻvitamin Eʼ was calculated based on the literature data (Skurikhin & Tutelyan, 2002; O'Brien, 2008). To obtain this indicator, the following recalculation factors are used: (α-tocopherol – 1.0; β-tocopherol – 0.4; γ-tocopherol – 0.1; δ-tocopherol – 0.01; α -tocotrienol – 0.3; β -tocotrienol – 0.05; γ- and δ-tocotrienol – 0.01). Information on the study of the estimated degree of the satisfaction of the body's needs in ω-3, ω-6 fatty acids and vitamin E at using the developed blends is presented in Table 5.

One dose (15 mL) of blend supplies the daily need for vitamin E:

- blend No. 1 - by 37.5%;
- blend No. 2 - by 24.9%;
- blend No. 3 - by 18.96%.

For people with low labor activity one dose (15 mL) of blend supplies the daily need for ω-3, ω-6 acids:

- blend No. 1 - by 35% and 70,8%, respectively;
- blend No. 2 - by 30.7% and 61.0%, respectively;
- blend No. 3 - by 22.1% and 43.7%, respectively.

For people with high labor activity one dose (15 mL) blend supplies the daily need for ω-3, ω-6 acids:

- blend No. 1 - by 24.0% and 47.2%, respectively;
- blend No. 2 - by 20.5% and 40.7%, respectively;
- blend No. 3 - by 14.8% and 28.7%, respectively

Thus, the recommended intake of blend No. 3 for people with high working activity corresponds to two doses (30 mL) per day.

Table 5. Expected degree of supplying the body's needs in ω -3, ω-6 and vitamin E by the developed blends equivalent (tocopherolequivalent)

Content of ω-3, ω-6, vitamin E		% from daily need		
		Blend No. 1	Blend No. 2	Blend No. 3
ω -3, %	in 100 g	158.0	135.7	98.2
	in 1 dose	24.0	20.5	14.8
ω -6, %	in 100 g	314.4	271.5	191.4
	in 1dose	47.2	40.7	28.7
Vitamin E	in 100 g	250.2	166.1	126.4
	in 1 dose	37.5	24.9	19.0

Currently, the study on the experimental determination of vitamin E and various phytocompounds in these blends is being conducted. The developed technology of blending of unrefined vegetable oils does not require technical re-equipment of enterprises, it is simple and convenient. Initial oils of blends in the quantities established by the formula are introduced into the mixing tank with the pre-started mechanism of the propeller mixer, while the oils are added in parts and alternating with each other. The oils are mixed for 15 minutes at the mixer rotation speed of 100 rpm.

The sensory analysis of the developed blends was carried out by practitioners with higher technological education (Fig. 2).

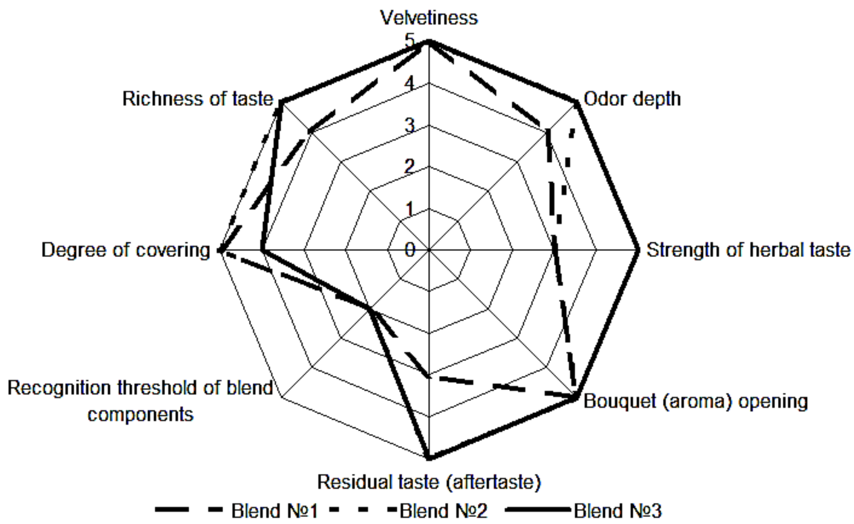

Figure 2. Organoleptic profile of the designed blends.

The descriptive characteristics of the blends are summarized in Table 6. Thus, the range of application of the developed blends is wide and it is rational to use them as a healthy food product both separately and as salad dressings, base for the sauces, mayonnaise and spreads of non-mass production with a short shelf life.

Table 6. Descriptive characteristics of blends

Indicator	Blend No. 1	Blend No. 2	Blend No. 3
Taste	Velvety-chalky, somewhat tasteless with unstable aftertaste	Warm, slightly pronounced herbal, with noble bitterness and moderate aftertaste	Cool, with spicy bitterness and a stable herbal aftertaste
Smell	Moderately cold, moderately intensive flavor of oil crops	Delicate, slightly perceptible herbal aroma	Warm, moderately herbal aroma
Colour	Amber	Intensive, deep amber	Delicate light-amber
Transparency	Transparent, without impurities		

CONCLUSION

Currently, mathematical methods for modeling of food compositions are intensively used in the food industry for the design of food formulas. The choice of the method of mathematical modeling for a particular food system is individual. It is rational to use simplex design in blending vegetable oils. The formulas of blends of regional unrefined vegetable oils from oil crops of the Saratov region with the optimal level and ratio ω-3/ω-6 acids were designed using this method, the effectiveness of which was confirmed by the results of empirical study. The resulting organoleptic profile of blends confirmed the acceptability of their wide application in food industry. Addition of the developed blends is organically included in the range of a daily diet of a healthy person, as its component and covers a significant part of the daily need of the body in essential substances. The use of this product line in nutrition is designed to contribute to the formation of the society of healthy and active of longevity in general, as well as to the minimizing the deficit of essential factors of nutrition in the child's body, athletes in the popular sports and sports of records.

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