

Внаслідок проведених порівняльних аналізів фізико-хімічних властивостей і жирнокислотного складу рослинних олій зроблено обґрунтований вибір. А саме – соняшникову, гарбузову, лляну, рижіву олії для складання купажів з раціональним співвідношенням  $\omega$ -6: $\omega$ -3 жирних кислот: у двокомпонентних (10:1, 5:1) та у трикомпонентних (5:1).

Обґрунтовано поєднання купажів рослинних олій із раціональним співвідношенням  $\omega$ -6: $\omega$ -3 жирних кислот. Вони відносяться до поліфункціональних фізіологічно активних продуктів з широким спектром технологічних властивостей, тому можуть використовуватись з жиророзчинними вітамінами (токоферолом та  $\beta$ -каротином). Це знижує окиснювальні процеси у ВКРО.

Купажовані рослинні олії – це система, в якій ПНЖК груп  $\omega$ -6 і  $\omega$ -3 присутні в певних співвідношеннях та схильні до окисного псування, більшою мірою за рахунок підвищеного вмісту ПНЖК. Відповідно до особливостей купажованих олій, як збагачуючі інгредієнти, використовувались жиророзчинні вітаміни Е (токоферол) і  $\beta$ -каротин, які є не лише фізіологічно важливими компонентами для організму людини, але й активними природними антиоксидантами. Встановлено, що додавання 0,2 % розчину  $\beta$ -каротину в кількості 3,75 г та 1 % розчину токоферолу – 2,5 г забезпечують 30 % добової потреби цих вітамінів.

Підтверджена доцільність поєданого використання токоферолу і  $\beta$ -каротину, що дозволяє стабілізувати окиснення і збільшити період індукції у 1,5–2 рази.

Розроблена технологія купажування і вітамінізації рослинних олій, яка впроваджена на Одеському заводі кісточкових і рослинних олій, ТОВ «АВА» (Україна).

Вирішуючи поставлені завдання при обґрунтуванні технологій купажування та вітамінізації, було доведено, що ці операції можливо виконувати на обладнанні, яке є майже на усіх олійно-жирових підприємствах. Запропонована технологія купажування передбачає лише два етапи (1-й етап – дозування рецептурної кількості олій 1 в температуру ємність; 2-й етап – дозування рецептурної кількості олій 2 в ємність з олією 1 і перемішування протягом 5–10 хв. при  $t=28-30$  °C). Вона не потребує на це великих витрат часу та дозволяє провести підготовку олій та змішування за 10–15 хв.

Ключові слова: рослинні олії, рафіновані олії, не рафіновані олії, вітамінізовані купажовані рослинні олії (ВКРО), жирнокислотний склад.

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## DEVELOPMENT OF A TECHNOLOGY OF VITAMINIZED BLENDED VEGETABLE OILS AND THEIR IDENTIFICATION BY THE FATTY ACID AND VITAMIN CONTENTS

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### 1. Introduction

Solving the problem of healthy nutrition is the most important and topical national task related to the social stability of society and the health of the population [1].

Recent studies have shown that polyunsaturated fatty acids (PUFAs) contained in vegetable oils are of great value to humans [2]. At present, the demand for them is formed both by the manufacturers themselves and by the recommendations of medical institutions and the World Health

Organization (WHO). They prove that 15–20 % of the total energy of the human body should be derived from the use of dietary oils, including less than 10 % of saturated fatty acids (SFAs), 6–10 % of polyunsaturated fatty acids (PUFAs) ( $\omega$ -6 – 5–8 %,  $\omega$ -3 – 1–2 %), 10–15 % of monounsaturated fatty acids (MUFAs), and less than 1 % of trans-isomer fatty acids (TIFAs). The unique spectrum of functional effects has led to a wide range of vegetable oils. The stimulating role of PUFAs for the protective mechanisms of the organism and, in particular, the increase of its resistance to infectious diseases has been proven [3].

The annual recommended rate of consuming vegetable oils is thirteen kilograms per person [3].

Dietary fats must have a certain fatty acid composition, good organoleptic properties, sufficiently high stability in storage and culinary processing, and combinability with other raw materials.

It should be noted that in the world structure of consumption, the main 17 oilseeds include 6.6 % of sunflower, 9.9 % of rapeseed, 22.4 % of palm, 26 % of soybean, and 15 % of pumpkin, flaxseed, and camelina.

Vegetable oils make up an important part of the human food ration. The chemical composition of vegetable oils, as objects modelled by nature, is unique [4]. However, the modern approach to evaluating the composition of the fatty acids of vegetable oils is corrected by the science of nutrition under a slogan “Through nutrition to health.” In vegetable oils, the chemical composition must be simulated by technological means [5]. Literature review [6] indicates a large difference in the content and ratio of the main irreplaceable acids of the  $\omega$ -6 and  $\omega$ -3 groups (linoleic and  $\alpha$ -linolenic acids) in vegetable oils.

Almost all fats have limited stability due to biologically and chemically determined hydrolysis as a result of self-oxidation [7].

The use of modern antioxidants, which have a synergistic effect, [8] allows a safe way to slow down significantly oxidative damage to fats and increase the shelf life of oil and fat products [9].

The introduction of antioxidants and synergists should be carried out at the initial stage of the technological process when the peroxide value is minimal [10].

Thus, antioxidants protect the human body from free radicals, exhibiting anticarcinogenic effect as well as blocking active peroxide radicals, thus slowing down the aging process.

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## 2. Literature review and problem statement

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Vegetable oils make up an important part of the human food ration. The chemical composition of vegetable oils, as objects modelled by nature, is unique. However, the modern approach to assessing the composition of the fatty acids of vegetable oils is corrected by the science of nutrition, which proposes a slogan: “Through nutrition to health” [11]. Therefore, it is necessary to simulate the chemical composition of vegetable oils by technological means. Literature review [9] indicates a large difference in the content and ratio of the main irreplaceable acids of the  $\omega$ -6 and  $\omega$ -3 groups (linoleic and  $\alpha$ -linolenic acids) in vegetable oils.

Vegetable oils are rich sources of MUFAs and PUFAs. Moreover, they contain a large number of biologically active compounds, including antioxidants [12].

The analysis of published data [12] shows that the use of only one type of oil does not help achieve the desired result.

There are several ways to solve this problem.

The first is the use, in a typical diet, of medical substances containing PUFAs of the omega-3 family.

The second is the creation of genetically modified oilseeds, with a given composition of PUFAs, followed by obtaining oils with the necessary fatty acid composition.

Eventually, it is necessary to choose the third method – blending (mixing) of vegetable oils, which is the most effective and economically justifiable way of designing fat products with appropriate PUFA composition and correlation to meet the requirements of the science of nutrition.

The advantage of using blended vegetable oils to correct PUFAs in the human body over special biologically active additives is that a vegetable oil is much cheaper than biologically active additives. Moreover, it is a traditional food product that does not cause complications and side reactions [9].

As vegetable oils are a source of natural antioxidants, prerequisites are created for the development of a technology of producing blended oils of a rational fatty acid composition with an extended shelf life and a certain caloric content of the product.

Thus, to achieve optimal ratios of  $\omega$ 6: $\omega$ 3 PUFAs and PUFAs:SFAs, it is necessary to use mixtures of several vegetable oils with a total content of 10 g per 100 g of the finished product.

As the research [8] has shown, an effective technological approach is to create two-component or multicomponent systems of natural vegetable oils enriched with biologically valuable additives (fat-soluble vitamins and phospholipids).

The important basis for the creation of dietary blended oils can be refined and unrefined oils: sunflower (the main and traditional type of oil produced in Ukraine), soybean, flaxseed, rapeseed, corn, camelina, pumpkin, and wheat germ. The main disadvantage of refined deodorized oils is the reduced content of biologically active substances and antioxidants that are responsible for resistance to oxidative damage in storage [13].

The shelf life of oilseed fat is not only a decisive factor in the supply chain of good quality food products. It is a criterion of quality that determines the choice of various branches of the food industry, which uses fats and oils as raw materials in production technologies [6].

The deterioration of the quality of many foods during storage is due mainly to the interaction of lipids with oxygen. Dietary fats are easily oxidized due to the chemical structure [10].

The oxidation processes that fatty acids undergo can accelerate or slow down as a result of the presence of natural antioxidants in fats [10].

It is important, for example, that the stability of vitamin A in oils is higher than in any other food [14]. Oils also contribute to the assimilation of vitamin A in the body. Specialists of the Institute of Nutrition of the Russian Academy of Medical Sciences (RAMS) recommend enrichment of food products in such a way that one serving contains at least 30 % of the RCR (recommended consumption rate) [15].

Diets containing mixed oils contribute to their use mainly for the formation of structural lipids that do not pass into the reserve and thus allow disease prevention [16].

The enrichment of sunflower oil with glycerides of linolenic acid to a rational content in the mixture (1–1.5 %) promotes synthesis of arachidonic acid in the body [17]. Adding vitamin A to an oil blend intensifies the synthesis of arachidonic acid, and the introduction of vitamin E covers an increased demand for it in the mixture of specific amounts of linolenic acid [18].

Vitamin A is found in vegetable products in the form of provitamins:  $\alpha$ ,  $\beta$ ,  $\gamma$ -carotenes or carotenoids. Carotenoids are a group of triterpenoids consisting of isoprene units. The structural formula of  $\beta$ -carotene composed of isoprene fragments is shown in Fig. 1.

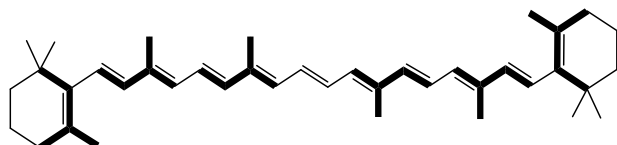


Fig. 1. The structural formula of  $\beta$ -carotene composed of isoprene fragments (highlighted in bold) the double bonds in which are in a conjugate state and trans-configurations

Thus, the enrichment of food products with PUFAs and vitamins can be considered an important direction in modern nutrition and in creating balanced formulations of food products of high nutritional value.

Normative and consumer requirements for mixtures of vegetable oils highlight the need for research and the creation of methods for calculating the balanced fatty acid composition of oil systems.

This technique allows obtaining two-component and multicomponent systems from vegetable oils, enriching them with fat-soluble vitamins, phospholipids and other biologically active components, using them in food, and obtaining fat-based products on their basis.

### 3. The aim and objectives of the study

The aim of the study is to develop new types of vitaminized blended vegetable oils (VBVOs) of a balanced composition for general nutrition and special diets.

To achieve this aim, the following tasks were set and solved:

- to compare the fatty acid composition and physicochemical parameters of vegetable oils and to make a choice for blending oils with the optimal ratio of  $\omega$ -6: $\omega$ -3 fatty acids;
- to establish rational concentrations of  $\beta$ -carotene and tocopherol to increase the stability of VBVOs and to ensure the daily need of the body in fat-soluble vitamins;
- to develop formulations that would be balanced as to the fatty acid and vitamin composition in accordance with the requirements of special nutrition, and to study their qualitative indicators;
- to substantiate the technologies of obtaining and vitaminizing vegetable oil blends with a rational composition of PUFAs.

### 4. Materials and methods of research on vitaminized blended vegetable oils

The objects of the study are the technology and the set of indicators of quality of new types of vitaminized blended

vegetable oils of a balanced composition. Here are samples of the vitaminized blended vegetable oils: No. 9 in Fig. 2 and No. 3 in Fig. 3.



Fig. 2. VBVO sample No. 9 (tricomponent): sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %) oils



Fig. 3. VBVO sample No. 3 (two-component): pumpkin (80 %) + flaxseed (20 %) oils

Organoleptic tests were carried out by a tasting group of 10 people. Physicochemical indicators of quality were determined according by standard methods.

The fatty acid composition was tested in accordance with DSTU ISO 5509-2002 “Fats and oils of animal and vegetable origin. Preparation of methyl esters of fatty acids (ISO 5509: 2000, IDT).” The sample preparation was as follows: a sample was dissolved in 2 ml of heptane. A pipette was used to add 200  $\mu$ l of NaOH methanolic solution, and the solution was shaken for 5–10 minutes; then 1 g of hydrogen sodium sulphate monohydrate was added, and the solution was carefully shaken again. After sedimentation of the salt, the upper layer containing the fatty acid methyl esters was separated. The resulting solution was used for chromatography according to DSTU ISO 5508-2001 “Fats and oils of animal and vegetable origin. Analysis by gas chromatography of methyl ethers of fatty acids (ISO 5508:1990, IDT).”

Detection of fatty acids was carried out on a Hewlett-Packard HP-6890 gas-fired ionization detector, with an S/S flow extractor, Sp2380 column, length 100 m, internal diameter of 0.25 mm, and coating thickness of 0.2  $\mu$ m.

The chromatographic conditions were the following: the injector temperature of 280  $^{\circ}$ C, the flow of 100:1, the detector temperature of 290  $^{\circ}$ C. The column operated in the mode of a constant flow at a rate of 1.2 ml/min, and the carrier

gas was helium. The temperature gradient of the columns' thermostat was from 60 to 250 °C.

The oxidation stability of vegetable oil blends was tested under various storage conditions:

1. The accelerated method of "active oxygen" was conducted according to DSTU ISO 6886-2003 "Fats and oils of animal and vegetable origin. Determination of oxidation stability (Accelerated oxidation test) (ISO 6886:1996, IDT)." The method is based on blowing air at constant speed through a layer of fat at constantly high temperature and the determination of the degree of the fat oxidation at certain time intervals. Into a hole, a blend in an amount of 100 g was introduced, and the substance was placed on a water bath heated to a temperature of  $75 \pm 2$  °C. Immediately after setting the temperature, air began to flow at a rate of 8 litres per hour. The reference was an oil sample without antioxidants. Measurements were taken for the initial peroxide, acid and anisidine values of all samples and at certain intervals (one hour to determine the PV, two hours to find the AcV, and three hours to determine the AnV). At the set intervals, 1 ml of a sample was taken from the hole into a pre-weighed flask with a pegged stopper and, after cooling, the flask was weighed again. The difference was found in the mass of the sample that was used to determine the oxidation index.

2. At room temperature with free access of light and air (auto-oxidation), the samples of blended vegetable oils were stored in glass cups at a temperature of  $24 \pm 2$  °C. As a reference, natural fats were used without adding the oils. In the process of storage, every 10 days, samples were taken to determine the peroxide, acid and anisidine values.

3. Under low-temperature storage without light access, samples of vegetable oils, reference and blended, were stored at a temperature of  $\pm 0.5$  °C. In the process of storing, each month, samples were taken for analysis and the peroxide, acid and anisidine values were determined.

The oxidation of the blends was stopped when the peroxide value had exceeded 10 mmol $\frac{1}{2}$ O/kg, the anisidine value was more than 6 c. u., and the acid value was more than 6 mgKOH/g.

To determine the antioxidant activity of the vegetable oils, the period of oxidation induction of the samples was calculated as the time during which there was a significant increase in the concentration of oxidation products. Antioxidant activity is the total inhibition effect due to a combination of elementary reactions of initiation, elongation and clogging of chains. The duration of the fats' oxidation before the end of the induction period was established by the kinetic curves of oxidation. The indicators of the end of the induction period were the content of peroxides at the level of 2.5 mmol $\frac{1}{2}$ O/kg (by the peroxide value), the beginning of the accumulation of free fatty acids (by the acid value) and the increase of the concentration of secondary oxidation products (by the anisidine value). The established period of the oxidation induction of the prototype was used to determine the effectiveness of the antioxidant action of the vegetable oils.

Activity was evaluated by the magnitude of the inhibition factor  $f$ , which was numerically equal to the number of chains broken up by one antioxidant molecule. The inhibition factor was calculated as the ratio of the time during which the induction period of the blended vegetable oil lasted to the time during which the induction period of the pure oil continued:  $f = \tau_i(\text{blend}) / \tau_0(\text{oil})$ .

## 5. Results of the study of the vitaminized blended vegetable oils

The organoleptic analysis of the vitaminized blended vegetable oils has shown that the taste and aroma of each of the blended oils were reflected in the finished vitaminized blended oil. Moreover, oils with pronounced taste and smell were detected even with a minimal proportion in the mixture, in particular, flaxseed and camelina oils.

The results of the organoleptic evaluation of the refined vitaminized blended vegetable oils are given in Table 1.

In order to determine the benefits between deodorized refined and unrefined oils so that to select an alternative to animal fat, quality indicators and changes in storage were studied.

The main cause of unpleasant taste and odour in food products is the development of oxidation and hydrolysis processes in the fatty component.

The results of the tests on the safety indices of the oils obtained are presented in Tables 2, 3.

Table 1

Organoleptic evaluation of the vitaminized blended vegetable oils

No. of the blend	Composition of the vitaminized blended vegetable oils	Taste	Smell
1	sunflower (89 %) + flaxseed (11 %)	A characteristic, very weak flavour of flaxseed oil	A brighter scent of flaxseed oil than of sunflower oil
2	sunflower (86 %) + camelina (14 %)	A faint taste of camelina oil	A faint smell that is typical of camelina oil
3	pumpkin (90 %) + flaxseed (10 %)	Does not have any pronounced taste of any of the oils	A faint smell that is inherent in both oils
4	pumpkin (85 %) + camelina (15 %)	A characteristic, very weak flavour of camelina oil	A richer scent of camelina oil than of pumpkin oil
5	sunflower (79 %) + flaxseed (21 %)	A characteristic flavour of flaxseed oil	A pronounced smell of flaxseed oil
6	sunflower (73 %) + camelina (27 %)	A pronounced taste of camelina oil	A scent that is typical of camelina oil
7	pumpkin (80 %) + flaxseed (20 %)	A faint flavour of flaxseed oil	A brighter scent of flaxseed oil than of pumpkin oil
8	pumpkin (72 %) + camelina (28 %)	A vivid taste of camelina oil	A vivid smell of camelina oil
9	sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %)	A very weak flavour of flaxseed and camelina oils	A very weak smell of camelina oil
10	pumpkin (77 %) + camelina (13 %) + flaxseed (10 %)	A characteristic, very weak flavour of camelina and flaxseed oils	A faint smell of camelina and flaxseed oils



**Table 2**  
Indicators of quality of the tested unrefined vegetable oils

Vegetable oils	Determined experimentally		
	Acid value, mgKOH/g	Peroxide value, mmol <sup>1</sup> / <sub>2</sub> O/kg	Anisidine value, c. u.
Sunflower	2.24±0.04	18.22±0.10	2.56±0.05
Mustard	1.62±0.03	22.95±0.12	1.71±0.04
Flaxseed	1.65±0.03	22.62±0.11	2.23±0.05
Pumpkin	2.45±0.04	11.80±0.08	6.33±0.09
Corn	0.83±0.01	17.06±0.09	3.31±0.07
Camelina	1.75±0.03	21.62±0.11	7.13±0.05
Apricot kernels	2.21±0.04	16.08±0.10	13.18±0.15
Plum kernels	2.77±0.05	37.25±0.22	4.76±0.08

When composing balanced mixtures of vegetable oils, it is necessary to take into account their density and effective viscosity, which will depend on the temperature and duration of the blending process. The results of determining the effective viscosity and density of the samples of the vegetable oils are given in Table 4.

**Table 3**  
Indicators of quality of the tested deodorized refined vegetable oils

Vegetable oils	Determined experimentally		
	Acid value, mgKOH/g	Peroxide value, mmol <sup>1</sup> / <sub>2</sub> O/kg	Anisidine value, c. u.
Sunflower	0.25±0.02	1.12±0.05	7.40±0.22
Camelina	0.40±0.04	1.83±0.07	6.60±0.20
Flaxseed	0.20±0.02	1.80±0.07	4.20±0.16
Pumpkin	0.35±0.03	1.09±0.05	5.50±0.19
Corn	0.85±0.10	6.80±0.20	4.10±0.15
Mustard	1.00±0.10	7.85±0.25	5.70±0.20

**Table 4**  
Effective viscosity and density of the vegetable oils

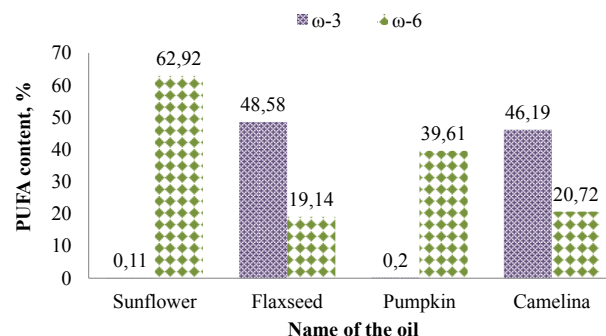
No.	The names of the vegetable oils	Effective viscosity, at 20 °C, MPa·s <sup>-1</sup>	Density, at 20 °C, kg/m <sup>3</sup>
1	Sunflower	54.6–59.8	920–923
2	Mustard	42.9–43.3	916–920
3	Flaxseed	52.7–53.0	934–936
4	Pumpkin	53.8–54.2	925–928
5	Corn	65.7–72.3	924–926
6	Camelina	72.0–78.2	919–933
7	Apricot kernels	45.2–45.7	914–920
8	Plum kernels	48.1–48.6	922–925

Since the object of research was vegetable oils, it was therefore essential to carry out a comparative analysis of the fatty acid compositions to replace animal fats with vegetable oils in meat products.

The fatty acid composition of the studied oils is presented in Table 5 and in Fig. 4.

**Table 5**  
The fatty acid composition of the studied refined vegetable oils

Fatty acids	The content of fatty acids in the oils, %			
	Sunflower	Camelina	Flaxseed	Pumpkin
C 14:0	0.07±0.03	0.06±0.03	–	0.09±0.03
C 16:0	6.83±0.30	5.73±0.40	4.88±0.40	11.83±0.20
c9-C16:1	0.09±0.03	0.12±0.03	0.07±0.03	0.12±0.04
C 17:0	–	–	0.07±0.02	0.08±0.02
C 18:0	3.44±0.10	2.15±0.07	4.96±0.10	5.86±0.20
c9-C18:1	24.91±0.50	15.16±0.40	21.55±0.70	41.47±0.70
9c,12t-C18:2n6	0.15	0.07	0.06	–
9t,12c-C18:2n6	0.11	–	–	–
9c,12c-C18:2n6	62.92±1.20	18.83±0.50	19.14±0.40	39.61±0.90
C 20:0	0.24±0.05	1.47±0.03	0.15±0.03	0.41±0.04
C 20:1	0.12	–	–	0.09
C 18:3n3	0.11±0.02	46.19±1.30	48.58±1.50	0.20±0.03
t-C18:3n3	–	0.37	0.21	–
C 20:2	–	1.76±0.10	–	–
C 22:0	0.75±0.06	0.38±0.05	0.17±0.03	0.12±0.02
C 22:1 Erucic	–	6.71±0.10	0.04	–
C 22:2	–	0.13	–	–
C 24:0	0.26±0.01	0.22±0.03	0.12±0.02	0.12±0.02
C 24:1	–	0.65±0.05	–	–
SFAs	11.59±0.30	10.01±0.30	10.35±0.30	18.51±0.30
MUFAs	25.12±0.70	22.64±0.70	21.66±0.60	41.68±1.30
ω-3 PUFAs	0.11±0.03	46.19±1.30	48.58±1.60	0.20±0.04
ω-6 PUFAs	62.92±1.8	20.72±0.70	19.14±0.60	39.61±1.00
C 18:2 trans	0.26±0.01	0.44±0.04	0.27±0.03	–
Total:	100	100	100	100



**Fig. 4.** The content of PUFAs of the ω-6 and ω-3 families in the refined vegetable oils

The content of β-carotene in the source vegetable oils is basically not more than 0.007 %; the average content of vitamin E is shown in Table 6.

Table 6

## The content of vitamin E in the vegetable oils

The names of the vegetable oils	Tocopherols, mg/100 g
Sunflower	40–70
Pumpkin	50–60
Flaxseed	48–50
Camelina	50–100
Corn	100–250

Previously, the solubility of the microbiological  $\beta$ -carotene preparation was investigated in the following concentrations: 0.2 %; 0.4 %; 0.6 %; 0.8 %, and 10 %; vitamin E was 1 %, 5 %, and 10 %. The amounts of  $\beta$ -carotene and vitamin E that were added to the blended vegetable oils, taking into account the daily requirement, are given in Tables 7 and 8.

Table 7

Concentration of  $\beta$ -carotene in the blended vegetable oils

Concentration of $\beta$ -carotene in the initial preparation, %	The amount of the $\beta$ -carotene preparation, g per 100 g of the blended vegetable oil
0.2	3.750
0.4	1.875
0.6	1.250
0.8	0.937
10.0	0.750

The main controllable indicators of changes in the quality of the oils during storage were peroxide and acidic values. Investigation of the oxidation stability of the blends was carried out by the accelerated method at a temperature of 70...75 °C with free access of light and air. As references, sunflower and pumpkin oils were used, which formed the

basis of the blends. Oxidation of the blends was stopped when the PV reached a value greater than 10 mmol $\frac{1}{2}$ O/kg (Table 9). If this number is higher, a blended vegetable oil is considered to be dangerous to health and is referred to a non-consumable product category.

Table 8

## Concentration of vitamin E in the blended vegetable oils

Concentration of vitamin E in the initial preparation, %	The amount of vitamin E, g per 100 g of the blended vegetable oil
1	2.50
5	0.50
10	0.25

The tests on the three-component blends have shown that both samples under study are not inferior to reference oil in terms of stability. To determine the stability of the blended oils, which were vitaminized by the addition of  $\beta$ -carotene in the amount of 0.2 % (3.750 g) and tocopherol solution (1 % (2.5 g)), accelerated oxidation was carried out. As references, samples of sunflower and pumpkin oils were used, vitaminized in the same quantities as the investigated blends (Table 10).

On the basis of the study of the quality indices of the vitaminized vegetable oil blends (vitaminized blended vegetable oils, VBVOs), the rational types were determined as follows: No. 3 (two-component): pumpkin (80 %) + flaxseed (20 %) and No. 9 (three component): sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %). The parameters were availability, cost and research results on the fatty acid composition of the specified VBVOs.

It has been proven that these VBVOs may be added to formulations that contain fatty components, and especially to meat products for the latter to comply with the nutritional standards [1].

Table 9

The dynamics of changes of the peroxide and acid values of the blended vegetable oils during storage,  $n=3$ ,  $p \leq 0.05$ 

Sample	Time of oxidation, min											
	AcV, mgKOH/g						PV, mol $\frac{1}{2}$ O/kg					
	0	60	180	300	420	600	0	60	180	300	420	600
Reference – sunflower oil	0.25	0.42	0.70	1.00	1.43	1.88	1.12	2.52	3.13	5.48	9.02	16.00
Reference – pumpkin oil	0.35	0.50	0.70	0.95	1.23	1.56	1.09	2.71	3.54	4.70	8.00	14.75
Two-component blended vegetable oils, the ratio of $\omega$ -6: $\omega$ -3 is 10:1												
Sunflower (89 %) + flaxseed (11 %)	0.24	0.63	1.07	1.67	2.53	3.49	1.32	1.71	3.43	6.52	11.00	19.54
Sunflower (86 %) + camelina (14 %)	0.27	0.48	0.73	1.00	1.28	1.57	1.38	1.73	2.68	4.04	6.69	10.50
Pumpkin (90 %) + flaxseed (10 %)	0.34	0.55	0.72	0.96	1.24	1.58	1.27	1.60	2.31	4.20	8.40	15.82
Pumpkin (85 %) + camelina (15 %)	0.36	0.50	0.67	0.90	1.19	1.40	1.36	1.62	2.30	3.77	6.54	10.17
Two-component blended vegetable oils, the ratio of $\omega$ -6: $\omega$ -3 is 5:1												
Sunflower (79 %) + flaxseed (21 %)	0.24	0.73	1.28	2.03	3.08	4.39	1.50	1.70	3.42	7.14	12.24	21.43
Sunflower (73 %) + camelina (27 %)	0.29	0.49	0.67	0.85	1.06	1.26	1.61	1.76	2.35	3.55	5.60	9.02
Pumpkin (80 %) + flaxseed (20 %)	0.32	0.52	0.75	0.98	1.31	1.70	1.45	1.92	2.77	5.61	10.05	17.39
Pumpkin (72 %) + camelina (28 %)	0.36	0.49	0.66	0.84	1.05	1.26	1.60	1.94	2.58	3.57	5.26	8.41
Three-component blended vegetable oils, the ratio of $\omega$ -6: $\omega$ -3 is 5:1												
Sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %)	0.26	0.51	0.68	0.91	1.15	1.40	1.26	1.73	2.52	4.00	7.51	13.07
Pumpkin (77 %) + camelina (13 %) + flaxseed (10 %)	0.34	0.49	0.67	0.89	1.13	1.35	1.26	1.61	2.76	4.83	7.68	12.10

Table 10

The dynamics of changes of the peroxide and acid values of the vitaminized blended vegetable oils during storage,  $n=5, \rho \leq 0.05$

Sample	Time of oxidation, min											
	AcV, mgKOH/g						PV, mol½O/kg					
	0	60	180	300	420	600	0	60	180	300	420	600
Reference – sunflower oil	0.25	0.27	0.38	0.51	0.70	0.94	1.12	1.22	2.56	6.83	7.21	9.44
Reference – pumpkin oil	0.35	0.43	0.62	0.75	1.03	1.04	1.09	1.92	2.37	3.60	7.05	10.15
Two-component vitaminized oil blends, the ratio of ω-6:ω-3 is 10:1												
Sunflower (89 %) + + flaxseed (11 %)	0.24	0.47	0.66	0.87	1.05	1.22	1.32	1.60	1.97	2.29	3.52	10.47
Sunflower (86 %) + + camelina (14 %)	0.27	0.41	0.53	0.64	0.71	0.77	1.38	1.50	1.76	2.21	3.44	7.54
Pumpkin (90 %) + + flaxseed (10 %)	0.34	0.44	0.58	0.72	0.88	1.05	1.27	1.47	1.68	2.13	3.60	10.65
Pumpkin (85 %) + + camelina (15 %)	0.36	0.45	0.57	0.70	0.83	0.94	1.36	1.47	1.68	2.00	3.44	6.78
Two-component vitaminized oil blends, the ratio of ω-6:ω-3 is 5:1												
Sunflower (79 %) + + flaxseed (21 %)	0.24	0.56	0.87	1.26	1.73	2.19	1.50	1.47	1.64	1.92	3.69	10.75
Sunflower (73 %) + + camelina (27 %)	0.29	0.42	0.52	0.58	0.66	0.74	1.61	1.56	1.68	1.97	3.19	7.22
Pumpkin (80 %) + + flaxseed (20 %)	0.32	0.43	0.58	0.74	0.93	1.15	1.45	1.58	1.76	2.29	4.10	11.29
Pumpkin (72 %) + + camelina (28 %)	0.36	0.45	0.57	0.69	0.79	0.90	1.60	1.68	1.76	2.00	2.95	6.15
Three-component vitaminized oil blends, the ratio of ω-6:ω-3 is 5:1												
Sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %)	0.26	0.40	0.51	0.60	0.69	0.76	1.26	1.47	1.68	1.97	2.70	6.87
Pumpkin (77 %) + camelina (13 %) + flaxseed (10 %)	0.34	0.42	0.52	0.63	0.76	0.91	1.26	1.45	1.64	2.09	3.56	8.80

**6. Discussion of the results of studying the vitaminized blended vegetable oils**

In developing the technology of blending vegetable oils, it was taken into account that the original oils had the following properties:

- different viscosity;
- mixing in different ratios;
- a high PUFA content.

Different combinations of the original vegetable oils were used to prepare the blended oils. The blended vegetable oils could be obtained at factories of different capacity that use certain hardware solutions.

The tasks solved when developing the blending technology were based of the following:

- minimal changes in technology;
- uniform distribution of oils;
- protection against oxidation;
- the possibility of using available equipment.

The general flowchart of obtaining blended vegetable oils is presented in Fig. 5.

The heating of oils, caused by different degrees of initial viscosity and density (Table 4), allows balancing the characteristics of these parameters.

Tempering of vegetable oils at high temperatures can catalyse oxidation processes in the blended system. High speed machining modes can cause splashing of blended oil. The consequence is an increase in the surface area of the oil that is in contact with air oxygen. During prolonged mixing, this

can lead to saturation of oil with oxygen, which will become a catalyst for oxidation processes.

Taking into account the above conditions, the following flowchart of obtaining two-component and three-component blends of vegetable oils is proposed, which involves the input of oil into a container simultaneously or alternately, stirring, with or without heating, and obtaining a planned blend (Fig. 6).

The rational direction and technological parameters of the staged preparation of two-component blended oil are the following:

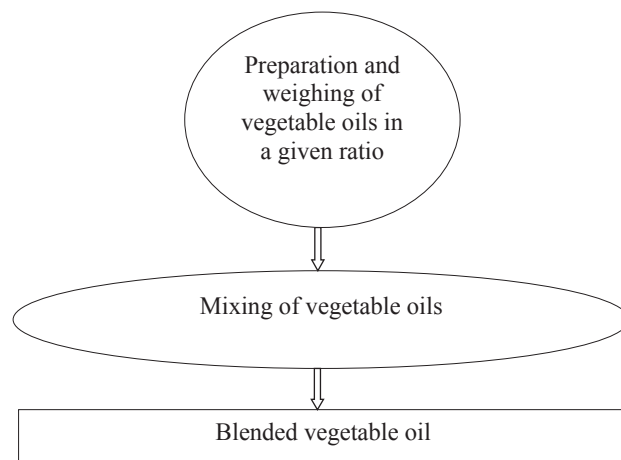


Fig. 5. The general flowchart of receiving blended vegetable oils

- the first stage – the dosage of the prescription amount of oil 1 in a temperature-maintaining container;
- the second stage – the dosage of the prescription amount of oil 2 into the container with oil 1 and mixing for 5.0...10 min at  $t=28...30$  °C.

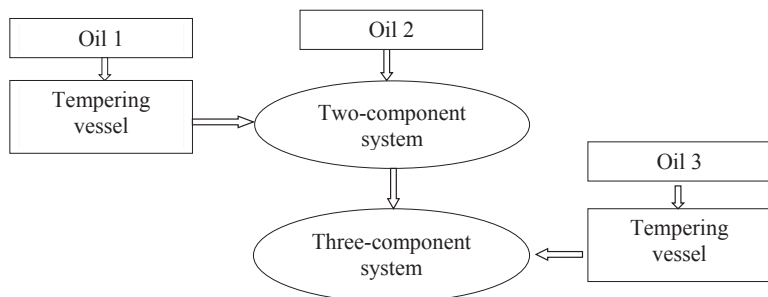


Fig. 6. The flowchart of blending vegetable oils

Consequently, it is possible to predict the mixing of the following refined vegetable oils:

- sunflower and flaxseed;
- sunflower and camelina;
- pumpkin and flaxseed;
- pumpkin and camelina.

If the blended system consists of three oils, then at the last stage of blending in the container with oils 1 and 2, a prescription amount of oil 3 is introduced.

For more accurate prediction of the possibilities of obtaining multicomponent blended vegetable oils with a given composition, mathematical calculation is required.

The method of processing the numerical data of the chromatographic analysis of vegetable oils is based on solving a system of equations with two or more unknowns.

The composition of a two-component blended oil, consisting of a mixture of two vegetable oils, is calculated by solving the system of equations (1) and (2):

$$\frac{m_a \times c_a^1 + m_b \times c_b^1}{m_a \times c_a^2 + m_b \times c_b^2} = 10, \quad (1)$$

$$m_a + m_b = 1, c_a^1, \quad (2)$$

where  $m_a$  is the mass of the vegetable oil a, kg;  $m_b$  is the mass of the vegetable oil b, kg;  $c_a^1$  is the concentration of linoleic acid in the vegetable oil a, %;  $c_a^2$  is the concentration of  $\alpha$ -linolenic acid in the vegetable oil a, %;  $c_b^1$  is the concentration of linoleic acid in the vegetable oil b, %;  $c_b^2$  is the concentration of  $\alpha$ -linolenic acid in the vegetable oil b, %.

The system of equations is solved in relation to the values of  $m_a$  and  $m_b$ .

The calculation of the composition of ternary mixtures of the vegetable oils is carried out in two stages. The purpose of the first stage is to determine the ratio of the two main components. The purpose of the second stage is to determine the proportion of the third component.

a) The calculation of the mass fractions of the vegetable oils when compiling a two-component mixture is calculated by solving the system of equations (1) and (2).

The system of equations (1) and (2) is solved with respect to the values of  $m_a$  and  $m_b$ . In the subsequent calculations, the prepared two-component mixture is considered as a homogeneous vegetable oil with the following constants:

- concentration of linoleic acid in the two-component mixed oil, %;
- concentration of  $\alpha$ -linolenic acid in the two-component mixed oil, %.

b) Calculation of the mass fraction of the mixed two-component oil and the third component in the preparation of a three-component mixture of the vegetable oils:

$$\frac{m_{(a+b)} \times c_{(a+b)}^1 + m_c \times c_c^1}{m_{(a+b)} \times c_{(a+b)}^2 + m_c \times c_c^2} = 9, \quad (3)$$

$$m_{(a+b)} + m_c = 1, \quad (4)$$

where  $m_{(a+b)}$  is the mass of the mixed two-component vegetable oil (a+b), kg;  $m_c$  is the mass of the vegetable oil c, kg;  $c_{(a+b)}^1$  is the concentration of linolenic acid in the mixed two-component vegetable oil (a+b), %;  $c_{(a+b)}^2$  is the concentration of  $\alpha$ -linolenic acid in the mixed two-component vegetable oil (a+b), %;  $c_c^1$  is the concentration of linoleic acid in the vegetable oil c, %;  $c_c^2$  is the concentration of  $\alpha$ -linolenic acid in the vegetable oil c, %.

The system of equations (3) and (4) is solved with respect to the quantities of  $m_{(a+b)}$  and  $m_c$ . Thus, in the preparation of a three-component blended oil, it is necessary to mix vegetable oils in the ratio of  $m_a$ ,  $m_b$  and  $m_c$ , respectively.

The result is the required ratio of linoleic and  $\alpha$ -linolenic acids in the blended system, and the starting data are the percentages of the vegetable oils in the blended system. As a result, the blended system has a predetermined balanced fatty acid composition.

The method allows making calculations for the preparation of blended systems of two and three vegetable oils.

Polyunsaturated fatty acids (PUFAs) are fatty acids whose molecules contain more than one single double bond, the general formula of which has the form  $\text{CH}_3(\text{CH}_2)_n(\text{CH}=\text{CH})_m(\text{CH}_2)_x\text{CO}_2\text{H}$ .

Important for the body are the polyunsaturated fatty acids of the  $\omega$ -3 and  $\omega$ -6 families, namely the ratio between them.

Polyunsaturated fatty acids of the  $\omega$ -3 family are:

- $\alpha$ -linolenic;
- eicosapentaenoic;
- docosahexaenoic.

Polyunsaturated fatty acids of the  $\omega$ -6 family are:

- linoleic;
- $\gamma$ -linolenic;
- arachidonic.

The source of polyunsaturated fatty acids is vegetable oils, but no individual oil has a rational fatty acid composition.

It should be noted that individual groups of people in connection with regional traditions or for other reasons consume mainly oils containing FAs of the  $\omega$ -6 group: sunflower and corn oils, and they almost exclude those oils that are rich in FAs of the  $\omega$ -3 group: flaxseed, soybean, rapeseed, and camelina. Therefore, it is necessary to create products with a balanced fatty acid composition.

The recommended ratio of PUFAs in the diet for a healthy person is 10:1, and for therapeutic and prophylactic purposes, it should be within 5:1–3:1 [7].



Taking into account the above conditions, the following general flowchart of vitaminizing the blended vegetable oils has been developed (Fig. 7).

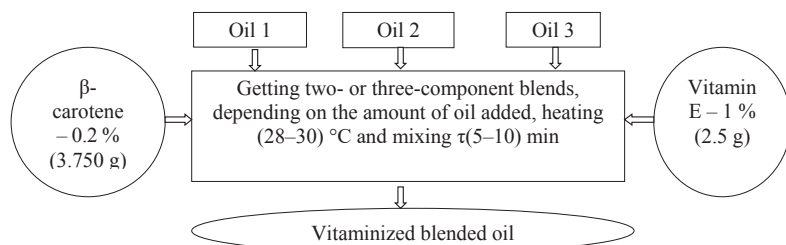


Fig. 7. The flowchart of vitaminizing blended vegetable oils

The effectiveness of the technology of vitaminizing blended vegetable oils is determined by the rational contents of β-carotene and tocopherol in the system.

The developed system of calculation of the component composition of the blended vegetable oil and the technology of preparation allowed developing the following formulations of blended systems with a certain ratio of PUFAs of the ω-6:ω-3 family:

Two-component refined blended oils (ω-6:ω-3 equal to 10:1):

- sunflower (89 %) + flaxseed (11 %);
- sunflower (86 %) + camelina (14 %);
- pumpkin (90 %) + flaxseed (10 %);
- pumpkin (85 %) + camelina (15 %).

Two-component refined blended oils (ω-6:ω-3 equal to 5:1):

- sunflower (79 %) + flaxseed (21 %);
- sunflower (73 %) + camelina (27 %);
- pumpkin (80 %) + flaxseed (20 %);
- pumpkin (72 %) + camelina (28 %).

Three-component refined blended oils (ω-6:ω-3 equal to 5:1):

- sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %);
- pumpkin (77 %) + camelina (13 %) + flaxseed (10 %).

The calculation method was used to obtain the following formulations of blended systems with a certain ratio of PUFAs of the ω-6:ω-3 family (Table 11).

Systems of two-component and three-component blended oils, in total 10 recipes, with a rational relation of ω-6:ω-3 have been obtained.

One of the factors that determine the quality of vitaminized blended vegetable oils is the taste-aromatic properties.

As can be seen from Table 1, blending of refined camelina oil with refined sunflower or pumpkin oils leads to the predominance of the taste properties of camelina oil. Similar conclusions can be drawn about flaxseed oil. There is also a noticeable tendency to soften the organoleptic characteristics of camelina and flaxseed oils in three-component vitaminized blended oils.

Therefore, the best organoleptic parameters are observed in the three-component vitaminized blended vegetable oils.

Vegetable oils are a source of essential substances necessary for the normal functioning of the human body, and they are characterized by high content of biologically active components and essential fatty acids.

Research on the fatty acid composition of various vegetable oils helps predict the possibility of using them in blends with rational fatty acid composition and ratio of ω-6:ω-3.

As research objects, refined and unrefined oils were used – sunflower, mustard, flaxseed, pumpkin, corn, camelina and fruit kernel (apricot, plum).

All samples of oil were made at the Odesa Stone Fruit and Vegetable Oils Plant (Ukraine) by the method of cold pressing.

To select components of the recipes of the vegetable oil blends, it was necessary to analyse the properties and function of each kind of oil in the human body in order to obtain a product with desired properties.

After analysing the quality indices of the studied oils, it was possible to conclude that the acid (1.1...1.2 mg KOH/g, according to DSTU 4350:2004) and anisidine values of

all the samples presented were within the normal range. The peroxide values of all samples of the investigated unrefined oils were beyond the permissible limits. For vegetable oils, the peroxide value, according to DSTU 4570:2006, should not exceed 10 mmol<sup>1</sup>/<sub>2</sub>O/kg.

Table 11

Formulations of the vitaminized vegetable oil blends and their fatty acid composition

Vegetable oil blends	Fatty acid content, %					Σ
	SFA	MUEA	ω-6 PUFA	ω-3 PUFA	trans	
Sunflower (89 %) + flaxseed (11 %)	11.45	24.74	58.11	5.44	0.26	100
Sunflower (86 %) + camelina (14 %)	11.38	24.77	57.01	6.56	0.28	100
Pumpkin (90 %) + flaxseed (10 %)	17.70	39.68	37.55	5.04	0.03	100
Pumpkin (85 %) + camelina (15 %)	17.28	38.68	36.54	7.46	0.04	100
Sunflower (79 %) + flaxseed (21 %)	11.33	24.39	53.73	10.29	0.26	100
Sunflower (73 %) + camelina (27 %)	11.16	24.46	51.52	12.55	0.31	100
Pumpkin (80 %) + flaxseed (20 %)	16.88	37.67	35.52	9.88	0.05	100
Pumpkin (72 %) + camelina (28 %)	16.13	36.35	34.32	13.08	0.12	100
Sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %)	11.26	24.47	10.71	53.27	0.29	100
Pumpkin (77 %) + camelina (13 %) + flaxseed (10 %)	16.59	37.20	11.01	35.11	0.09	100

It has been established that deodorized refined oils not only have a neutral taste and smell, and therefore do not affect the organoleptic parameters of the pates, but are also more resistant to the influence of external factors.

As can be seen from Table 4, sunflower, flaxseed, pumpkin, corn and camelina oils have higher values of effective viscosity due to the presence of a free hydroxyl group in the molecule.

According to a set of quality indicators, samples of refined corn and mustard oils have high values of acid (1.85 and 2.25 mg KOH/g, respectively) and peroxide (6.8 and 7.85 mmol<sup>1</sup>/<sub>2</sub>O/kg) values. Therefore, four samples of the

refined oils were selected for further research and creation of blends, with the best characteristics and quality indicators; those were namely sunflower, camelina, flaxseed and pumpkin oils.

By the chemical composition, all oils consist of triglycerides and higher fatty acids; therefore, there was a need to investigate and analyse the fatty acid composition of the selected oils.

Fatty acids are carboxylic acids whose molecules contain from four to thirty-six carbon atoms. In the composition of living organisms, more than two hundred fatty acids have been detected, but about twenty have become very common. Depending on the presence of double bonds between carbon atoms, all fatty acids are divided into saturated without double bonds and unsaturated with double bonds. The most common of unsaturated fatty acids are palmitic (C16) and stearic (C18).

According to the modern classification of fatty acids, the number of C atoms from the end of the chain of a fatty acid to the closest double bond allows referring it to a particular group:  $\omega$ -3,  $\omega$ -6 or  $\omega$ -9 (Fig. 8).

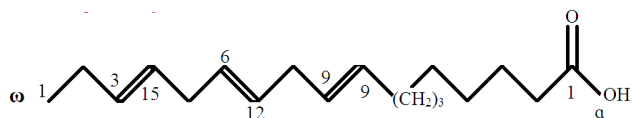


Fig. 8. Identification of carbon atoms by the classification of fatty acids exemplified by  $\alpha$ -linolenic acid

As can be seen from Table 5, flaxseed and camelina oils contain the highest values of  $\alpha$ -linolenic, eicosapentaenoic and docosahexanoic acids – C18:3. Besides, a large amount of linoleic acid C18:2, which belongs to the family of  $\omega$ -6 polyunsaturated fatty acids, is found in sunflower and pumpkin oils.

The analysis of the composition of the vegetable oils shows that they contain different fatty acids. However, none of them completely possesses a rational ratio of fatty acids that would correspond to the physiological needs of humans. Therefore, the essential task is to combine two or more oils between them to achieve a balanced ratio [19].

While evaluating the biological value of oils, polyunsaturated fatty acids are considered to be highly important because they have high biological activity, regulate the exchange of free fatty acids, affect the blood pressure and elasticity of the blood vessels, and so on.

During the analysis of the fatty acid composition, it was found that the content of saturated and polyunsaturated fatty acids in the studied oils was significantly different and affected the distinction of properties.

From the conducted tests of the PUFA content, shown in Fig. 4, it is clear that the content was as follows: 63.03 % in sunflower oil, 67.72 % in flaxseed oil, 39.81 % in pumpkin oil, 66.91 % in camelina oil, and 12.4 % in animal fat.

The refined oils, represented in Fig. 4, are characterized by a rather large discrepancy of the values of the  $\omega$ -6: $\omega$ -3 ratio – from 625:1 to 0.6:1.

Therefore, a preliminary assessment of the fatty acid content of the original oils and their content of PUFAs allows for the creation of two-component mixtures of vegetable oils with a rational composition of  $\omega$ -6: $\omega$ -3 fatty acids.

The main task of this stage of research is the study of the possibility of enriching the blended vegetable oil with biologically active components.

The provision of adequate amounts and ratios of vitamins is determined, on the one hand, by essentiality and, on the other hand, by broad participation in metabolic processes (water soluble vitamins) and by the effect on the functional state of cellular and subcellular membranes (fat soluble vitamins). In modern conditions, with an increase in the structure of the diet of the proportion of refined products [20], conditions are created for the development of vitamin deficiencies. However, under conditions of oxidative stress, the daily body's need for vitamins increases. Therefore, it is necessary for formulations to include vitamins and, above all, fat soluble vitamins-antioxidants such as A, E, C, and  $\beta$ -carotene [21].

Sources of vitamin E are vegetable oils (soybean, sunflower, corn, etc.), nuts, oilseeds, legumes, etc. Sources of vitamin C have a variety of vegetables and fruits. Carrots, sweet peppers, parsley, citrus and apples are rich in  $\beta$ -carotene. It should be borne in mind that with an increase in the content of PUFAs, especially long-chain, the need for vitamin-antioxidants increases in the diet. For example, it has been established that adding 1 g of PUFAs of the  $\omega$ -3 family to the diet requires additional 5 mg of vitamin E [22].

A blended vegetable oil is a system in which PUFAs of the  $\omega$ -6 and  $\omega$ -3 groups are present in certain ratios; it is prone to oxidative damage to a greater extent due to the increased content of PUFAs.

In accordance with the characteristics of the blended oils as enriching ingredients, fat-soluble vitamins E (tocopherol) and  $\beta$ -carotene were used in the study. Vitamins E and  $\beta$ -carotene are physiologically important components for the human body; besides, tocopherols are active natural antioxidants.

As can be seen from Table 6, the content of vitamin E in the vegetable oils varies greatly. The presence of vitamin E in the original oils provides a certain resistance to oxidation processes.

It is still essential to add vitamin E to a blended system, which in its composition contains oils with insignificant content of tocopherols.

According to the WHO, the daily human need for vitamins E and  $\beta$ -carotene is 15 mg and 5 mg, respectively.

Taking into account the above, the following proportion of vitaminizing the blended oils was determined by calculation: 30 % of the daily norm of vitamin E and 30 % of the daily norm of  $\beta$ -carotene. Such amount of vitamins should be contained in 20 g of cooked vegetable oil (the amount of 20 g corresponds to the daily rate of consumption of oils).

In the course of the tests, it was found that solubility does not depend on the concentration of  $\beta$ -carotene and vitamin E. All preparations of these concentrations are well soluble in oil.

The effectiveness of the technology of vitaminizing the blended vegetable oils with the required composition of PUFAs is determined by the uniform distribution of vitamins in the system and stability. For further laboratory tests, samples of  $\beta$ -carotene with a concentration of 0.2 % (3.750 g) and vitamin E at a concentration of 1 % (2.5 g) were selected, which ensure uniform distribution throughout the volume of oil.

It should be noted that the solubility and uniformity of the distribution of 10 % of  $\beta$ -carotene and 10 % of vitamin E are considerably complicated, given the high concentration. Therefore, the use requires a long time and higher temperatures for mixing.

Both vegetable oils themselves and mixtures in the process of storage undergo oxidation and hydrolysis, which in the future can lead to unwanted changes in the composition

of the fatty product and significantly degrade its quality and safety. In the mixture of vegetable oils, there are oils with different fatty acid composition, and the behaviour of such blends during storage may differ from the oxidation of individual oils.

While analysing the results of Table 9, it is evident that during the experiment, all blended oils underwent changes of different depths. At the initial time of oxidation, the AcV and PV of sunflower and pumpkin oils were close. The addition of camelina and flaxseed oils in different ways affected the stability of the controlled oil samples. In particular, the content of hydrolysis products (AcV) and peroxide oxidation products (PV) clearly shows a relatively higher stability of pumpkin oil and blends with it. The high stability of the blended and natural pumpkin oils can be explained by the less saturated fatty acid composition compared to the highly unsaturated sunflower oil. While comparing the stability of two-component blends, it is evident that the addition of flaxseed oil positively affects the accumulation of spoilage products in all experimental samples. Thus, for the sample consisting of flaxseed (11 %) and sunflower (89 %) oils, the stability decreased, which was manifested in an increased of the PV up to 19.54 mol $\frac{1}{2}$ O/kg, compared with the reference sample of sunflower oil, with the PV being 16.00 mol $\frac{1}{2}$ O/kg after 600 min of accelerated oxidation. With an increase in the proportion of flaxseed oil to 21 %, the intensity of oxidation increased, as was evidenced by the change in the PV, which at the end of the experiment was 21.43 mol $\frac{1}{2}$ O/kg. Similar data were obtained when determining the AcV in all studied samples with flaxseed oil.

High durability is acquired by blending when adding camelina oil. In particular, the addition of 14 % of camelina oil reduces the intake of sunflower oil from 16.00 to 10.50 mol $\frac{1}{2}$ O/kg after 600 min of oxidation, and the introduction of 27 % – up to 9.02 mol $\frac{1}{2}$ O/kg. Similar values were obtained in the study of pumpkin oil blends with camelina oil as to the PV and AcV. This can be explained by the traditionally high resistance of cruciferous family seed plants, which often have sulphur-containing concomitant substances.

After analysing the results of the AcV and PV shown in Table 10 by the accelerated method, a conclusion can be made that the addition of vitamins as antioxidant supplements was effective in all the samples tested. The use of  $\beta$ -carotene and tocopherol solution has been shown to slow down the flow of hydrolytic and oxidative damage in the vitaminized blended and reference vegetable oils. By comparing the characteristic values at the end of the experiment, the following was established: the best indicators of antioxidant ability had been exhibited by the blends with camelina oil. It has been found that this oil contributes to a deceleration of peroxidation processes 1.5...2 times compared with the reference samples. The best indicators of stability were the following samples of blended vegetable oils: pumpkin (72 %) + camelina (28 %) and pumpkin (85 %) + camelina (15 %), the PVs in which were 6.15 and 6.78 mol $\frac{1}{2}$ O/kg after 600 min of the experiment. The stability of the vitaminized blends with sunflower oil is somewhat inferior to the vitaminized blend of pumpkin oil, apparently because of the lower initial content of natural antioxidants.

Thus, it has been established that the combined use of vitamins E and  $\beta$ -carotene allows stabilization of the processes of oxidation of vegetable oils. In our opinion, each of these components shows not only its own antioxidant properties but also can be a mutual synergist.

The addition of vitamin E and  $\beta$ -carotene to the blended vegetable oils gave an extra opportunity to increase the phys-

iological properties of the blended vegetable oils and enhance antioxidant protection.

When solving the problems of substantiating the blending and vitaminization technologies, it has been proven that these operations can be performed with equipment that is present in almost all oil and fat processing factories. The proposed blending technology involves only two stages (stage 1 is the dosage of the prescription amount of oil 1 in a temperature-maintaining container; stage 2 is the dosage of the prescription amount of oil 2 in the container with oil 1 and mixing for 5.0...10 min at  $t=28...30$  °C). It does not require much time and allows the preparation of oil and mixing within 10–15 minutes.

It is expedient to use the ten created vitaminized blended vegetable oils in formulations of protein-fat emulsions in the amount of 15–20 % and in recipes of poultry meat pastes in the amount of 10 % [1].

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## 7. Conclusions

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1. Based on studying the quality and fatty acid composition of vegetable oils, ten recipes of vegetable oil blends have been developed. The advisable use in products of balanced composition is the following: in healthy people's nutrition, the  $\omega$ -6: $\omega$ -3 ratio should be equal to 10:1, and for therapeutic and prophylactic diet, the  $\omega$ -6: $\omega$ -3 ratio should be equal to 5:1.

2. The calculation method was based on the composition of two-component and three-component recipes of blended oils enriched with tocopherol and  $\beta$ -carotene. The level of vitaminization has been determined as follows: tocopherol 1 % – 2.5 g (30 % of daily requirement) and  $\beta$ -carotene 0.2 % – 3.750 g (30 % of daily requirement). The samples of vegetable oils, blends of vegetable oils and vitaminized blends of vegetable oils were studied for oxidation resistance. It has been found that the blended vegetable oils have the same ability to oxidation processes as the vegetable oils themselves. It has also been determined that adding selected vitamins-antioxidants (vitamin E and  $\beta$ -carotene) to the blended vegetable oils can suspend oxidation processes and increase stability 1.5–2 times.

3. On the basis of the conducted organoleptic tests, the composition of PUFAs was calculated, taking into account the stability of the blends during storage. The study has determined the following optimal blends: two-component VBVO No. 3: pumpkin (80 %) + flaxseed (20 %) oils and three-component VBVO No. 9: sunflower (77.5 %) + camelina (13 %) + flaxseed (9.5 %) oils. It has been proven that these VBVOs may be added to formulations that contain fatty components and especially meat products to comply with the nutrition science requirements.

4. The technologies of obtaining and vitaminizing vegetable oil blends with a rational composition of PUFAs, which corresponds to the physiological needs of a person, have been substantiated. When solving the problems of justifying the blending and vitaminization technologies, it has been proven that these operations can be performed on equipment that is present in almost all oil and fat processing factories. The proposed blending technology involves only two stages: stage 1 is the dosage of the prescription amount of oil 1 in a temperature-maintaining container; stage 2 is the dosage of the prescription amount of oil 2 in the container with oil 1 and mixing for 5.0...10 min at  $t=28...30$  °C). It does not require much time and allows the preparation of oil and mixing within 10–15 minutes.

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