ASPECTS OF PRODUCTION OF FUNCTIONAL EMULSION FOODS

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Abstract: Criteria for evaluation of functional properties of emulsion foods are formulated. Balanced fat bases of emulsion sauces are simulated by using liquid vegetable oils of various fatty acid groups: oleic, linoleic, and linolenic. The optimum ratio of the components of an antioxidant-emulsifying complex is established. The efficiency of the antioxidant-emulsifying complex (AEC) for the emulsion sauce technology is experimentally confirmed with the help of sea-buckthorn or red palm oils and lecithin. It is established that the introduction of the AEC into the fatty base of emulsion products promotes the deceleration of oxidation processes in the product. The new emulsion sauce recipes and technology are scientifically justified.

Key words: emulsion sauce, antioxidant, lecithin, sea-buckthorn oil, red palm oil

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INTRODUCTION

The concept of rational nutrition that underlies the current ideas of nutrition and health postulates the need for a new approach to the composition, properties, and, consequently, technologies of food products, which should not only meet the needs of the human organism in foodstuffs and energy but also provide it with the whole range of necessary macro- and microingredients, contributing to the prevention of alimentary-dependent diseases and preserving human health and longevity.

The new generation of food products includes those enriched with physiologically functional ingredients (functional products and enriched foodstuffs) designed to be consumed within food rations by all age groups of the healthy population and to reduce the risk of food-related diseases.

Physiologically, functional food ingredients can render a favorable effect on one or several physiological functions and metabolic processes in the human organism as they are consumed systematically in amounts of 10 to 50% of the daily physiological standard.

Fatty products for healthy nutrition must have a high nutritional value and contain the necessary set of polyunsaturated fatty acids (PUFAs), and the ratio of ω-3 to ω-6 acid families must be 1 : (5–10) at the optimal daily intake of specific acids. This ratio can be ensured by the necessary set and combination of vegetable oils, including blended oils.

Vegetable oils with high contents of PUFAs and balanced fatty acid compositions make it possible to produce emulsion fatty products of high biological efficiency. In addition, we should note that the oxidation of oils and fats in products with high contents of PUFAs and fat-soluble vitamins is the main factor that reduces their shelf life; therefore, the prevention of the oxidation of lipids is a major problem during the production and storage of fatty products.

The oxidation of oils and fats is a complex radical–chain process. The initial products of oxidation are structurally different peroxides and hydroperoxides, which are called the *primary products of oxidation*. Their transformations result in the formation of the *secondary products of oxidation:* alcohols, aldehydes, ketones, and acids with various lengths of their carbon chains, as well as their diverse derivatives, which, accumulating in oil, take part in the formation of the order and flavor of oxidized oil [4].

Overall, the mechanism of fat oxidation and antioxidant effects can be represented as follows:

free radical R, derived from a fatty acid or from its acyl under the effect of several factors, interacts with oxygen and forms a peroxide radical:

$$R\cdot + O_2 \rightarrow ROO\cdot,$$

which can interact with another unsaturated fatty acid or its acyl, forming a new free radical and a hydroperoxide:

$$ROO\cdot + RH \rightarrow ROOH + R\cdot.$$

In the initial period, which is called the *induction period*, the reaction flows slowly. At this time, the process can be accelerated in the presence of *pro-oxidants* or, reversely, decelerated due to the effect of antioxidants.

As hydroperoxides accumulate and disintegrate, forming new radicals, the process accelerates sharply:

$$2ROOH \rightarrow ROO\cdot + RO\cdot + H_2O.$$

The oxidation rate depends on the fat–acid composition of oils; the position of an unsaturated fatty acid in the triacylglycerol molecule; the amount, position, and geometrical configuration of double linkages; the presence of trace quantities of lipoxygenases in the oil–fat raw material; humidity; temperature; the presence of mixed-valence metals; and light [8].

In fats containing polyunsaturated fatty acids, oxidation occurs much faster than in saturated fats. As is known, the oxidation rate of a fatty acid grows proportionately to the number of double linkages in a molecule and to the amount of methylene groups between each pair of double linkages. Thus, the ratio of oxidation rates of oleic and linoleic acids ranges from 1 : 12 to 1 : 40, depending on product type, and arachidonic and linolenic acids are oxidized three and two times faster than linoleic acid. The structure of PUFAS affects the structure of secondary products of oxidation, in particular, the formation of volatile low-molecular aldehydes and ketones with low flavor thresholds, whose presence in a product gives it the odor and flavor of rancid oil [4].

Fats and oils differ significantly in their natural oxidative stability, which depends not so much on the composition and structure of fatty acids but on the presence of natural antioxidants, such as tocopherols, tocotrienols, carotenoids, and phospholipids, which inhibit the chain reactions of free-radical oxidation.

Food antioxidants are substances that decelerate the oxidation of, primarily, unsaturated fatty acids within lipids. Depending on their action mechanism, the substances that decelerate the process of fat oxidation are divided into the following three groups.

1. Antioxidants, chemical compounds that bind free lipid radicals, forming low-active radicals and thus interrupting the self-oxidation reaction. This mechanism is used by phenolic antioxidants, such as, tocopherol.

The introduction of antioxidant AH leads to the formation of new radicals A, which are much more stable that radicals R, slowing down the reaction and finally, under certain conditions, decelerating it sharply:

$$AH + R\cdot \rightarrow A\cdot + RH$$
$$AH + ROO\cdot \rightarrow ROOH + A\cdot$$
$$A + R\cdot \rightarrow AR.$$

2. Antioxidant synergists, substances that amplify the activity of antioxidants but that themselves do not have or have weak antioxidant properties. Efficient synergists are deoxidants, for example, ascorbic acid, which is used to protect oil–fat products from oxidation. Synergists SH_2 can reduce the A radicals without reacting with the ROO radicals,

$$SH_2 + 2\,A\cdot \rightarrow S + 2AH.$$

3. Complex formers, substances that are also antioxidant synergists, but the mechanism of their action is based on the formation of chelate complexes with metals. Citric and milk acids, as well as their salts, and lecithin are used for this purpose [1].

Some compounds, like lecithins and lactates, perform complex functions. Antioxidants help extend the shelf life of food products, protecting them from the rancidification of oils, fats, and fat components.

In practice, mixtures of antioxidants and complex formers are used to achieve synergetic effects at the same or even lower concentrations.

The use of antioxidants in fatty products for healthy nutrition must comply with the rational nutrition concept, preferably using natural food additives that are effective at low concentrations.

Taking into consideration the above, the design of oxidation-resistant emulsion fatty products for healthy nutrition is of scientific and practical interest, which requires broader basic and applied research and the incessant focus of the producers on this group of products.

GOAL AND OBJECTIVES OF RESEARCH

The goal of this paper is to develop recipes and to evaluate the quality of emulsion sauces balanced by their fatty-acid composition and containing an antioxidant-emulsifying complex, which includes natural carotenoids, tocopherols, and phospholipids.

The following objectives were set to meet the goal: to design a balanced fatty base of an emulsion salad sauce, including the ω-3 and ω-6 fatty acids; to study and analyze the composition and properties of lecithin and vegetable oils with high carotenoid and tocopherol contents; to investigate the synergetic effect of tocopherols, carotenoids, and phospholipids; to produce the antioxidant-emulsifying complex for emulsion sauces and to probe into its antioxidant properties; to develop the recipes and technology of oxidation-resistant emulsion sauces; and to examine the quality parameters of the developed sauces during their storage.

OBJECTS AND METHODS OF RESEARCH

Pursuant to the objectives set, we used generally accepted and original methods of research, including gas-liquid chromatography and photocolorimetry.

Crude fat was sampled and prepared in line with the requirements of ISO 5555-91 "Animal and vegetable fats and oils. Sampling" and ISO 661-89 "Animal and vegetable fats and oils. Preparation of test sample."

When studying the physicochemical parameters of vegetable oils and mayonnaise sauces, we determine:

- density with the help of a pyknometer, which represents a small glass vessel with a ground plug, whose neck has a mark to show the filling limit;
- melting temperature in a capillary vessel, open at both ends;
- acid number with the titration method. The method is based on dissolving oil in an ester–alcohol mixture (2 : 1) with the subsequent quick titration of the sample by an alkali in the presence of a phenolphthalein indicator until faint pink coloring;
- peroxide number by a method based on the interaction reaction of oil and fat oxidation products (peroxides and hydroperoxides) with potassium iodide in a solution of acetic acid and chloroform with the subsequent quantitative determination of the precipitated sodium thiosulfate;
- iodine number by the Hanus method. This method is based on the use of bromine iodide (IBr_2) as a reagent, which is formed by mixing bromine with iodine in glacial acetic acid. Bromine iodide associates with the double linkages of unsaturated fatty acids, and its surplus is titrated by sodium thiosulfate in the presence of potassium iodide and water;
- the quantity of β-carotene and tocopherols in oil was determined by the colorimetric method;
- the fatty-acid composition of oil was determined

by gas-liquid chromatography. The determination of the fatty-acid composition was preceded by converting fatty acids into methyl esters. The obtained chromatograms of the methyl esters of fatty acids were identified, and the quantitative content of fatty acids was calculated by peak areas in percent, using the standard methods; and

- the oxidation resistance of oils was determined by accelerated oxidation, when oils were kept at room temperature in standard conditions.

RESULTS AND DISCUSSION

The main aspects of the formation of functional properties of mayonnaise sauces imply solving the following problems:

the reduction of the product's caloric capacity by changing its ratio of fat phase to water phase. To decrease product fatness, part of oil was replaced with the water phase using natural emulsifying additives that ensure the required product texture;

the fatty-acid composition of the fat phase of emulsion sauces was improved to reach the recommended balance between saturated, monounsaturated, and polyunsaturated fatty acids by admixing (blending) oils in which various fatty acids prevailed;

increasing shelf life and preventing microbiological, hydrolytic, and oxidative spoilage by using natural highly active antioxidant additives, including tocopherols, carotenoids, and phospholipids.

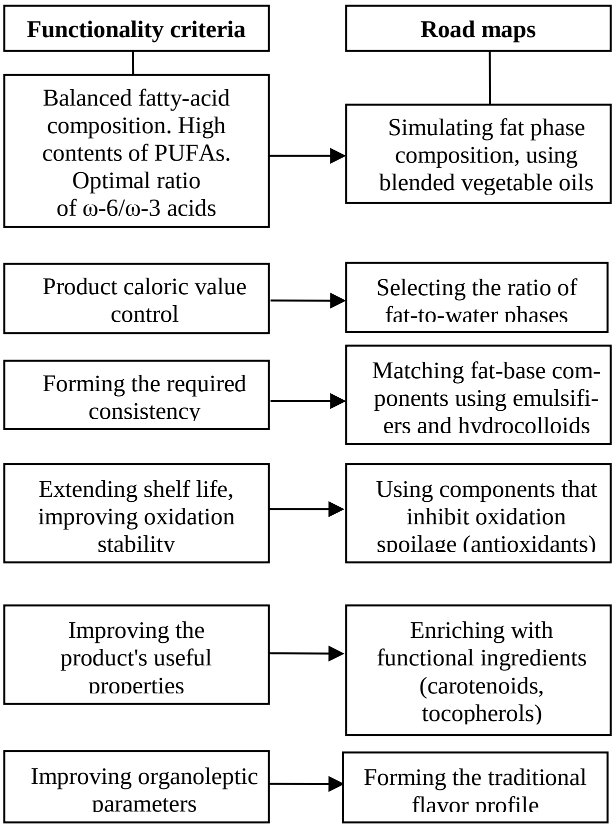

Fig. 1. Functionality criteria of emulsion products.

To justify the choice of vegetable oils used as fat-base components, we investigated the fatty-acid composition of several liquid vegetable oils.

The fatty-acid composition of vegetable oils, calculated from the chromatograms, is given in Table 1.

Table 1. Fatty-acid composition of vegetable oils

Fatty acids	Fatty acid contents, g/100 g of product			
	Refined vegetable oils			
	sunflower	sunflower high oleic	soybean	rape-seed
Total fatty acids	**94.90**	**97.90**	**94.90**	**95.40**
Saturated, including:	**11.30**	**10.60**	**13.90**	**6. 68**
oleic	0	0	0	0
caproic	0	0	0	0
caprylic	0	0	0	0
capric	0	0	0	0
lauric	0	0	0	0
myristic	0	0	traces	0
palmic	6.20	4.20	10.30	4.80
stearic	4.10	4.20	3.50	1.40
arachidic	0.30	0.60	traces	0.30
behenic	0.70	0.90	traces	0.20
Monounsaturated, including:	**23.80**	**69.0**	**19.80**	**56.30**
caproleic	0	0	0	0
lauroleic	0	0	0	0
myristoleic	0	0	0	0
palmitoleic	traces	1.70	0	0.30
oleinic	23.70	67.30	19.80	54.00
gadoleic	0	0	0	1.00
erucic	0	0	0	1.00
Polyunsaturated, including:	**59.80**	**18.30**	**61.20**	**32.40**
linoleic	59.80	18.30	50.90	22.50
linolenic	0	0	10.30	9.90
arachidonic	0	0	0	traces

We chose high oleic sunflower oil as a fat-base component. Sunflower high-oleic oil in its biochemical composition is very close to olive oil, which allows us to use it alongside olive oil in sauce recipes and to obtain a product with similar characteristics and properties. When designing balanced fat bases for mayonnaise sauces, we chose rapeseed oil alongside sunflower high-oleic oil. Note that the fatty-acid composition of low-erucic rapeseed oil is characterized by a very low level of saturated fatty acids, a relatively high level of monounsaturated fatty acids, and a mean level of polyunsaturated fatty acids. Rapeseed oil is a source of linolenic acid, which is absent in sunflower oil. We also considered the possibility of introducing soybean oil as a source of linoleic and linolenic acids into the fat base of mayonnaise sauces.

When choosing a composition of vegetable oils for the design of the fat base of functional mayonnaise sauces, we were guided by the following:

- reaching the $\omega_6 : \omega_3$ ratio of fatty acids in triacylglycerols close to the optimum, ensuring the therapeutic properties of products, namely, hypocholesterolemic and hypolipidemic effects;

- reaching in hypocholesterols a fat phase containing 2% of linolenic acid (of the total content of fatty acids), ensuring antisclerotic effects in combination with vitamins E and β-carotene; and

- ensuring the oxidation stability of the finished product.

The most rational way of creating a balanced fatty-acid composition of the fat base and controlling the ratio of the $\omega_3 : \omega_6$ essential fatty acids is the blending of vegetable oils that belong to different fatty-acid groups.

We studied the possibility of creating composite mixtures of vegetable oils with the required fatty-acid composition, controlled in line with the current requirements of the balanced nutrition concept. The biological efficiency of the calculated compositions was evaluated by the degree of approximation of their fatty-acid composition to the biologically optimal ratio of the $\omega_6 : \omega_3$ fatty acids, 5 : 1–10 : 1.

We propose that the recipes of emulsion sauces include two-component mixtures of vegetable oils consisting of sunflower high-oleic and rapeseed oils (70 : 30) and (60 : 40), as well as sunflower high-oleic and soybean oils (50 : 50). The fatty-acid composition of the chosen vegetable oils and the two-component mixtures are given in Table 2.

Table 2. Fatty-acid composition of vegetable oils in binary mixtures of vegetable oils

Fatty acids	Fatty-acid content, % of the total					
	sunflower oil (S_ho)	rapeseed oil (Ro)	soybean oil (So)	Two-component mixture		
				S_ho / Ro (70 : 30)	S_ho / So (50 : 50)	S_ho / Ro (60 : 40)
SFAs	10.60	6.68	3.90	9.40	7.30	8.60
MUFAs	69.00	56.30	19.80	65.20	44.40	62.60
PUFAs	18.30	32.40	61.20	22.50	39.70	20.40
Including:						
($C_{18:2}$) (ω_6)	18.30	22.50	50.90	19.60	34.60	20.40
($C_{18:3}$) (ω_3)	–	9.90	10.30	2.90	5.10	5.00
$\omega_6 : \omega_3$	–	2 : 1	5 : 1	7 : 1	7 : 1	5 : 1

* Legend: SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; ($C_{18:2}$), linoleic acid; ($C_{18:3}$), linolenic acid; S_ho, sunflower high-oleic oil; Ro, rapeseed oil; and So, soybean oil.

Thus, the designed compositions ensure ratios of linoleic acid (ω_6) to linolenic acid (ω_3) in a lipidic complex of (5.0 : 1.0) and (7.0 : 1.0), i.e., close to the optimal ratio of fatty acids that is responsible for the therapeutic properties.

The determinative factor in developing mayonnaise sauce technologies is the maximum preservation of the native state of the composition and properties of the finished products during storage. It is important to study the characteristics of the fat-phase oxidation process in mayonnaise emulsion sauces during storage and the regularities that are responsible for the rate and direction of this process.

The causes of spoilage of mayonnaise sauces are oxidation processes, resulting in the formation of decomposition products of fatty acids; the oxidation of triglycerides and the isomerization of initial acids. The accumulation of oxidation substances, such as peroxides, hydroperoxides, aldehydes, ketones, and oxy compounds, impairs the organoleptic and rheological properties of products, and reduces their physiological and biological value.

We suggest that the formulas of emulsion sauces should include an antioxidant-emulsifying complex, obtained by mixing natural phospholipids (lecithin) and vegetable oils, rich in natural antioxidants (carotenoids and tocopherols), and we suggest red palm oil and sea-buckthorn oil as such.

We have chosen these products because they contain antioxidantly and biologically effective substances, important for the human organism.

The formula of mayonnaise sauces should have an antioxidant composition: carotenoids–tocopherols–phospholipids.

We investigated the antioxidant effect of the tocopherols and carotenoids of red palm oil and sea-buckthorn oil blended with phospholipids on the oxidizing ability of oils during storage.

The quality of the samples under study was controlled by determining oxidative spoilage indicators, the peroxide number and the acid number. In order to intensify the process, we used accelerated oxidation: the samples were stored at room temperature, in the light, and with free access of air. The following oil compositions used to produce mayonnaise sauces served as check samples without adding antioxidant components:

- composition 1, a mixture of vegetable oils (check);
- composition 2, vegetable oils / phospholipids;
- composition 3, vegetable oils / red palm oil;
- composition 4, vegetable oils / sea-buckthorn oil;
- composition 5, vegetable oils / red palm oil / phospholipids; and
- composition 6, vegetable oils / sea-buckthorn oil / phospholipids.

The dynamics of the peroxide and acid numbers during the storage of fatty compositions with red palm and sea-buckthorn oils and their mixtures with phospholipids vs. the composition of vegetable oils without phospholipids and oils rich in carotenoids and tocopherols are shown in Figs. 3–5.

Analysis of the stated data shows that the peroxide number of the vegetable oil check sample without antioxidants increased from 1 to 17 mmol of active oxygen/kg. The peroxide number of the vegetable-oil compositions with phospholipids increased from 1 to 14.9 mmol of active oxygen/kg over 14 days of accelerated oxidation. The peroxide number of composition 3 increased from 1.9 to 12 mmol of active oxygen/kg over

14 days of accelerated oxidation. When introducing (red palm and sea-buckthorn) oils with antioxidant effects in combination with phospholipids, we observed the lowest growth of the peroxide number: it increased from 1 to 10.1 mmol of active oxygen/kg.

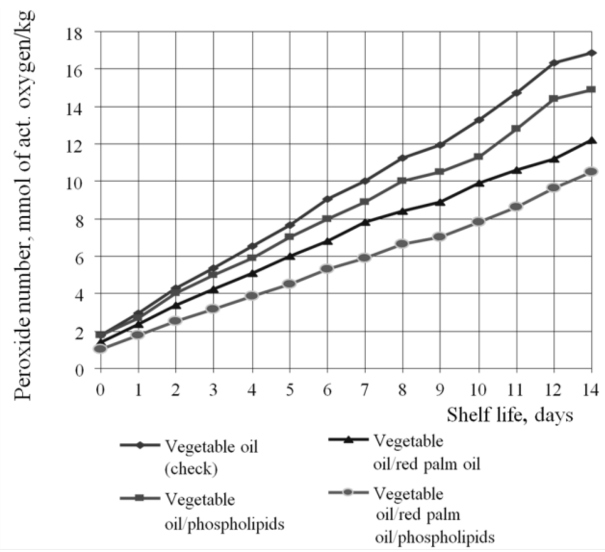

Fig. 2. Peroxide number dynamics during the oxidation of fatty compositions with red palm oil, red palm oil and phospholipids, and without adding such.

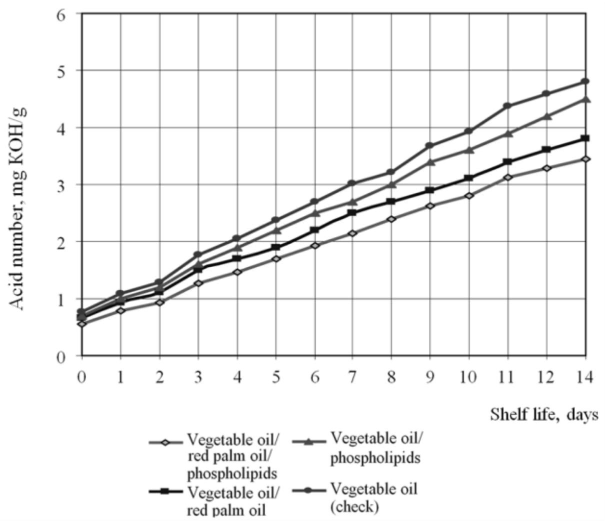

Fig. 3. Acid number dynamics during the oxidation of fatty compositions with red palm oil, red palm oil and phospholipids, and without adding such.

Comparison of the results allows us to conclude that red palm and sea-buckthorn oils in combination with phospholipids have antioxidant properties, can slow down oxidation processes in unsaturated fatty acids, and display a synergetic effect during their joint introduction into fatty compositions.

It follows from the above that natural carotenoids, tocopherols, and phospholipids can be used as components of fatty emulsion products to improve the antioxidant potential of fat phases.

It has been established that the introduction of emulsion products of the antioxidant-emulsifying complex based on red palm and sea-buckthorn oils into the fat base helps increase the shelf life of finished products.

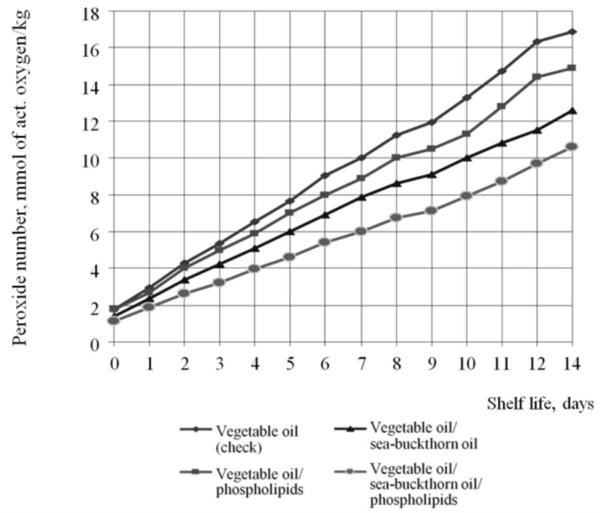

Fig. 4. Peroxide number dynamics during the oxidation of fatty compositions with sea-buckthorn oil, sea-buckthorn oil and phospholipids, and without adding them.

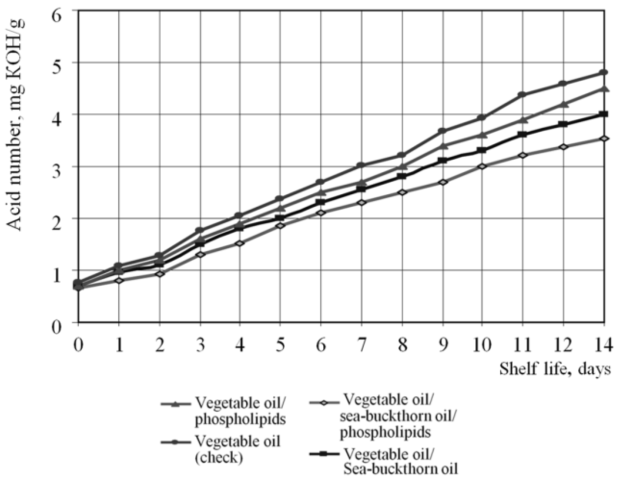

Fig. 5. Acid number dynamics during the oxidation of fatty compositions with sea-buckthorn oil, sea-buckthorn oil and phospholipids, and without adding them.

The antioxidant-emulsifying complex is developed by mixing food phospholipids with vegetable oils. For their uniform distribution in the fat base and increased efficiency, phospholipids and vegetable (sea-buckthorn or red palm) oils are dissolved in deodorized oil at 60–70^{0}C in ratios of 1 : 4–1 : 5, which corresponds to the following percentage: refined deodorized vegetable oil, 80%; phospholipids, 10 %; and red palm oil, 10 %.

For sea-buckthorn oil, the ratio is the following: refined deodorized vegetable oil, 85 %; phospholipids, 10 %; and sea-buckthorn oil, 5%.

The new product is characterized by high contents of carotenoids, 65–70 mg/100 g, and tocopherols, 45–50 mg/100 g (Table 3).

Table 3. Tocopherol and carotenoid contents in the antioxidant-emulsifying complex (AEC)

Parameter	AEC based on	
	red palm oil (AEC 1)	sea-buckthorn oil (AEC 2)
Vitamin E, mg/100 g	43	46
Carotenoids, mg/100 g	67	69
including:		
β-carotene	21	23

The physicochemical and organoleptic parameters of the AEC based on red palm and sea-buckthorn oils with phospholipids are given in Table 4.

Table 4. Physicochemical and organoleptic parameters of the antioxidant-emulsifying complex

Parameter	AEC with	
	red palm oil (AEC 1)	sea-buckthorn oil (AEC 2)
Consistency	Fluid	
Color	Orange-yellow	
Odor and flavor	Low, typical of vegetable oil used and phospholipids. Fusty, sour, or any foreign odors are inadmissible.	
Mass fraction of moisture and volatile substances, %	0.3 ± 0.05	0.3 ± 0.05
Mass fraction of phospholipids, %	10.0 ± 0.05	10.0 ± 0.05
Mass fraction of vegetable oil, %	80.0 ± 0.05	85.0 ± 0.05
Mass fraction of red palm/sea-buckthorn oil, %	10 ± 0.05	5 ± 0.05
Acid number of oil, mg KOH/g, no more than	2.5	3.5
Peroxide number, mmol of active oxygen/kg, no more than	10.0	10.0
Density (15°C) g/cm^3	0.924	0.922
Refractive index (20°C)	1.474	1.476
Viscosity (20°C), c П	55.1	58.4
Iodine number, % J_2	123	126
Vitamin E, mg/100 g	43	46
Carotenoids, mg/100 g	67	69
including:		
β-carotene	21	23

Egg products are traditionally used to produce mayonnaises as emulsifiers; the main emulsifier in mayonnaise is egg yolk, more precisely, lecithin and other phospholipids contained in it. In addition to its emulsifying properties, yolk affects the organoleptic characteristics of products (flavor and consistency).

Unlike mayonnaises, salad sauces do not contain egg products. The need arises to select the right emulsifier that would replace egg powder in terms of nutritive value and that would allow us to produce stable emulsions with the required viscosity, rheology, and possibly longer shelf life.

We have developed a antioxidant-emulsifying complex that contains 10% of phospholipids.

Note that food vegetable phospholipids are used successfully as emulsifiers to produce dietary emulsion products, such as margarines, mayonnaises, and spreads. In addition, lecithins are used as liquefiers of chocolate mass and as stabilizers of various jelly products.

The main functions of phospholipids in food products are related to emulsification, viz., the ability to form and keep in a homogeneous state both oil-in-water and water-in-oil emulsions, as well as to stabilize various systems. The above functions make phospholipids traditional food additives, deliberately put into food products to give them the required properties, to improve their antioxidant potential, and to increase their shelf life, since some phospholipids display antioxidant effects.

However, the use of phospholipids in the emulsion product technology is not limited to solving only technological problems; their high physiological activity preconditions the creation of new biologically wholesome fatty products.

Our research has shown that food vegetable phospholipids have high biological activity, which manifests itself in favorable effects on lipid exchange and the liver functionality, reducing hypercholesterolemia and improving the antioxidative functions of the human organism. As natural emulsifiers, phospholipids ensure the transfer of fat-soluble vitamins, promoting their oxidation in the liver, conversion in the tissues, etc.

Proceeding from the biological activity of phospholipids and the current ideas of balanced nutrition, it has been established that the average food ration of an adult must contain 3.5–5.0 g of lecithin [5].

Tables 5 and 6 show comparative evaluation of the physicochemical parameters and chemical composition of the antioxidant-emulsifying complex and egg powder.

Table 5. Comparative evaluation of the physicochemical parameters of food additives

Parameter	Parameter value		
	Egg powder	AEC with	
		red palm oil (AEC 1)	sea-buckthorn oil (AEC 2)
Mass fraction, %: Moisture and volatile substances	6.15–6.50	0.30–0.35	0.30–0.35
Lipids	33.10–34.15	78–86	78–86
Phospholipids	9.15–9.98	10	10
Proteins	45.20–45.90	absent	absent
Minerals	4.35–4.48	4.58–4.87	4.58–4.87
Cholesterol	2.30–2.40	absent	absent
Acid number of lipids isolated from the product, mg KOH/g	4.50–4.75	0.90–1.10	1.0–1.20
Peroxide number of lipids isolated from the product, mol of active oxygen /kg	5.15–5.30	2.28–2.58	2.48–2.88

Comparative analysis of the physicochemical parameters and chemical composition of the examined additives for the production of emulsion sauces has shown that the AEC qualitative composition is an alternative to egg powder.

Thus, the selection of surface-active substances is of special importance for the technology of low-fat combined emulsions, including salad sauces. A pertinent system of emulsifiers helps obtain highly stable products of various compositions and reduced caloricity. In addition, the main concepts of choosing emulsifying–stabilizing systems should primarily be focused on the group of natural compounds and their synthetic analogs with the maximum functionality that help create a broad range of emulsion products with preset properties.

The complex studies undertaken have helped us develop recipes for low-calorie emulsion sauces that do not contain animal components.

Table 6. Chemical composition and nutritive value of food additives

Parameter	Parameter value	
	Egg powder	AEC
Mass fraction of vitamins, mg/100 g:		
E	absent	43–46
β-carotene	0.15	22
Mass fraction of polyunsaturated fatty acids, %	10.15–10.60	43.20–43.60

Table 7. Recipes of functional emulsion sauces

Components	Content of recipe components, %	
	Sauce of 35% fatness	Sauce of 45% fatness
Two-component mixture of vegetable oils	25.0	35.0
AEC	10	10
Total fats	35.0	45.0
Stabilizer	3.8	2.9
Sugar sand	2.0	2.0
Food cooking salt Extra	1.0	1.0
Mustard	0.75	0.75
Milk acid of 80%	0.34	0.34
Sodium benzoate	0.2	0.2
Flavoring agent Yolk	0.008	0.008
Water	56.9	47.8
Total	100	100

* Legend: AEC 1, the antioxidant-emulsifying complex with red palm oil; AEC 2, the antioxidant-emulsifying complex with sea-buckthorn oil.

When designing the recipes of emulsion sauces, we took into account consumer preferences in sauce caloricity. We have proposed emulsion sauce recipes with fat mass fractions of 35 and 45%.

The recipes of functional emulsion sauces are given in Table 7.

A special feature of the proposed technology is the exclusion of the repasteurization stage due to the absence of egg products in the mayonnaise sauce recipe. The classical scheme of mayonnaise production envisages that, before the introduction of egg products, the mayonnaise paste, pasteurized at 80°C, is cooled down to 60°C to avoid the denaturation of the albumen of the egg products. After the introduction of egg products, the mixture is repasteurized. We propose that the AEC, which replaces egg powder, is to be introduced in the amount of 10% at the emulsification stage at 35–40°C, which allows preserving the vitamin complex.

Longer shelf life is a priority in creating new products and technologies.

Emulsion sauces, due to their specific composition, are products unstable during storage; therefore, the longer shelf life of these products is very topical. The use of the AEC as a component containing natural antioxidants, such as tocopherols, carotenoids, and phospholipids, slows down oxidation processes during storage.

The studied samples of emulsion salad sauces were kept in consumer packaging, made of polymer materials and admitted for use by the Russian Ministry of Public Health.

The emulsion sauces were stored at 4 $\pm$ 2°C for 9 months.

The intensity of oxidation and hydrolysis processes during storage was studied, and the dynamics of the peroxide number of the fat phase of emulsion sauces was analyzed. The dynamics of the peroxide number of the developed emulsion sauces during storage is given in Fig. 6.

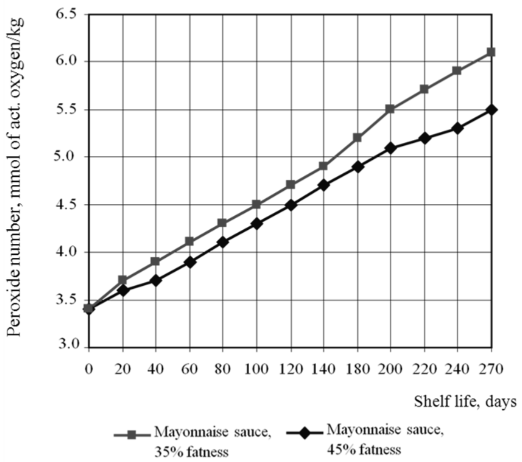

Fig. 6. Peroxide number dynamics during the storage of emulsion sauces at 4 $\pm$ 2°C.

Analyzing the storage dynamics of peroxide numbers, we may conclude that the intensity of accumulation of primary oxidation products increases as the mass fraction of fat in emulsion sauces decreases, which is associated with the intensification of the hydrolysis process. Thus, the peroxide number of a sauce containing 35% of the fat phase increased from 3.4 to 6.2 mmol of active oxygen/kg over 9 months of storage at 4 $\pm$ 2°C, by stayed within the set standard (no more than 10 mmol of active oxygen/kg).

Changes in the organoleptic parameters of the quality of emulsion sauces during storage at 4 $\pm$ 2°C are given in Table 8.

Table 8. Organoleptic parameters of the quality of emulsion sauces during storage

Month number	Appearance, consistency	Odor and flavor	Color
	Standard requirements		
	Uniform creamy product; singular air bubbles are admissible.	Flavor is slightly pungent, sourish, with the odor and flavor of the introduced flavoring and aromatic additives	From light yellow to yellow, uniform throughout its mass.
	Emulsion sauce		
1	Uniform creamy product with singular air bubbles	Pleasant, sourish, without marked signs of bitterness	From light yellow to yellow, uniform throughout its mass.
2			
6			
4			
5			
6			
7			
8			
9			

It follows from the data in Table 8 that all parameters remain within the standard during storage.Changes in the physicochemical parameters of the quality of emulsion sauces during storage are given in Table 9.

Table 9. Physicochemical parameters of the quality of emulsion sauces during storage

Parameters	Parameters of emulsion sauces (after 9 months of storage), with fatness of		Standard requirement
	45%	35%	
Mass fraction of fat, %	45.0 ± 0.5	35.0 ± 0.5	At least 15
Mass fraction of moisture, %,	62.0 ± 0.5	52.0 ± 0.5	In line with product specifications
Acidity, % of conversion to acetic acid	0.7 ± 0.1	0.8 ± 0.1	No more than 1.0
Emulsion stability, % of intact emulsion	99.0 ± 0.5	99.0 ± 0.5	At least 98
Hydrogen index (pH) at 20^0C	4.5 ± 0.2	4.2 ± 0.2	4.0–4.7
Effective viscosity at 20^0C and a shear rate of $3s^{-1}$, Pa/s	15 ± 0.0	13 ± 0.0	5.0–20.0

Thus, the table data show that the physicochemical parameters of the sauces under study did not change and remained within the standard during storage. Data about the microbiological parameters of emulsion sauces during storage are given in Table 10.

Table 10. Microbiological parameters of the quality of emulsion sauces during storage

Parameters	Shelf life of emulsion sauces at 4 ± 2°C, days										Standard
	Emulsion sauce of 45%					Emulsion sauce of 35%					
	0	60	120	180	270	0	60	120	180	270	
(Coliform bacteria), absent in g	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1
Pathogens, including salmonellae absent in g	25	25	25	25	25	25	25	25	25	25	absent in 25 g
staphylococci, absent in g	Not found	Not found	Not found	Not found	Not found	Not found	Not found	Not found	Not found	Not found	Inadmissible
QMAFAnM, CFU/g	Not found	Not found.	Not found.	Not found.	Not found.	Not found.	Not found.	Not found.	Not found.	Not found.	Inadmissible
Yeast, CFU/g	50	55	70	110	160	55	80	90	130	180	$5*10^2$
Mold, CFU/g	0	2	5	8	15	0	3	8	14	20	50

Table 11. Nutritive and energy values of emulsion sauces

Parameter	Emulsion sauce of 35% fatness	Emulsion sauce of 45% fatness
Proteins,%	1.62 ± 0.01	1.62 ± 0.01
Lipids, %	35.0 ± 0.1	45.0 ± 0.1
including phospholipids	1.0 ± 0.1	1.0 ± 0.1
Linoleic acid, %	12.1 ± 0.1	15.5 ± 0.1
Linolenic acid, %	1.73 ± 0.01	2.2 ± 0.1
Carbohydrates, %	3.9 ± 0.1	3.9 ± 0.1
Carotenoids, mg/100 g	6.7 ± 0.1	6.7 ± 0.1
Tocopherols, mg/100 g	4.3 ± 0.1	4.3 ± 0.1
Energy value, kcal	326	427

Analyzing the obtained data we may conclude that the samples of emulsion sauces of different fatness are characterized by high microbiological purity both on the day of production and during the whole shelf life Coliform bacteria were absent in 0.01 g of products at the end of the shelf life. *Staphyloccocus aureus* and pathogenic microorganisms, including salmonellae, were not found in the standardized masses of products through the whole storage period. Yeast and mold were also within the standard. Thus, during the whole storage period the growth of microorganisms was insignificant, and the sauces preserved sufficient microbiological purity. The positive results of essaying the safety of emulsion sauces allowed us to establish the shelf life of 7 months at a temperature regime of 4 ± 2^oC.

Data about the nutritive and energy values of the developed emulsion sauces are given in Table 11.

The above data show that the developed mayonnaise sauces have low caloricity and a balanced ratio of ω_6 : ω_3 fatty acids; contain physiologically valuable ingredients, such as phospholipids, carotenoids, and tocopherols, in amounts that comply with the standard physiological needs for food substances; and can be used as functional food products.

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