

The solution to the problem of developing an oxidation-stable dressing with high nutritional value based on unrefined first cold-pressed linseed, corn and sesame oils is considered. The objects of the study are the following indicators: antioxidant, fatty acid composition, induction period of accelerated oxidation of oils, blends and finished products. The rational range of oil ratios in the blend, enriched with α -linolenic acid, stabilized against oxidative spoilage due to natural antioxidants – tocopherols, sesamol, sesamol, is substantiated. The ratio of linseed, corn and sesame oils is 1:2:1, respectively. The characteristics of the blend are as follows: the ratio of ω -3: ω -6 fatty acids is 1:1.7; the induction period of accelerated oxidation (at 80 °C) – 4.1 h. A model sample of the dressing was produced using the developed blend. It was proven that the sample of the dressing of the proposed composition retains its organoleptic and physico-chemical parameters (titratable acidity, dry matter content, acid and peroxide values of the oil fraction) during 30 days of storage at a temperature of 8 ± 1 °C. A feature of the obtained results is the possibility of increasing the nutritional value of the dressing based on unrefined oils while preserving the extended shelf life of products. From a practical point of view, the development of such products allows expanding the range of competitive dressings with high nutritional value. An applied aspect of using the obtained scientific result is the possibility of modeling the composition of dressings or other oil products based on valuable oil raw materials, depending on the ratios of the oil base components of the product

Keywords: blended oil, dressing, tocopherols, sesamol, α -linolenic polyunsaturated fatty acid, induction period of accelerated oxidation

DEVELOPMENT OF THE COMPOSITION OF ANOXIDATION-STABLE DRESSING WITH HIGH NUTRITIONAL VALUE

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1. Introduction

The problem of preserving the health of the population is closely related to the need for scientific substantiation of the

composition of complete food products that are used in the daily diet [1–3]. Oil-based dressings (salad sauces) occupy a special group among them. These are low-calorie salad dressings prepared on the basis of oils, vegetable and fruit

and berry purees, dairy products and other additives. Food acids, herbs, spices, etc. are added to them in order to form a taste. Due to the trend of increasing demand for healthy food products, there is a need to expand the range of salad sauces and dressings [4, 5]. Despite the fact that dressings have never been the main and independent dish, their importance cannot be overestimated. Such sauces, depending on the ingredient composition, can enrich the main dish with various biologically active substances (vitamins, minerals, dietary fiber, antioxidants, polyunsaturated fatty acids (PUFA), etc.) [6, 7].

The need to develop fat-containing food products, including dressings, balanced in basic physiological indicators is obvious. For health oils, the determining factor is the ratio of essential fatty acids in triacylglycerols. But it is worth noting that the formula of the so-called "ideal fat" with fatty acid composition: oleic – 50 %, linoleic – 20 %, saturated – no more than 30 %, does not take into account the content of α -linolenic acid [3, 8]. However, no vegetable oil in nature has a balanced fatty acid composition in terms of human nutrition physiology. In this regard, the priority area of research is the development of a multicomponent composition of linoleic-oleic, linoleic-linolenic and oleo-palmitic oils. Such a composition should be balanced in polyunsaturated fatty acids (PUFA) of ω -3 and ω -6 groups (linoleic and α -linolenic), enriched with biologically active substances of antioxidant action. The introduction of oxidation-stabilized products based on such compositions into the diet not only has an unconditional physiological and social significance, but also creates theoretical and economic prerequisites for the industrial implementation of the results of such development.

Therefore, research aimed at finding and substantiating factors affecting the composition of dressings with high nutritional value and extended shelf life will provide an opportunity to expand the range of useful dressings based on valuable unrefined vegetable oils. The usefulness of such products should be manifested in the increased content of PUFA of the ω -3 group and at the same time stability against oxidative spoilage. The obtained data are intended to structure the methodology for substantiating the formulations of oil components of dressings with high nutritional value. The obtained scientific results of the specified area are relevant for food production, as there is a need to increase the nutritional value of dressings and increase their shelf life. This will make it possible to expand the range of such health products, which, in addition to high nutritional value, have increased resistance to oxidative spoilage.

2. Literature review and problem statement

In [9], an oil-vinegar dressing with potentially health-giving properties was developed. The following component composition of the product is substantiated:

- a mixture of oils enriched with ω -3 PUFA (refined sunflower and soybean oils),
- different types of vinegar (white and red wine, pomegranate, apple, olive) as sources of natural biophenols.

Emulsification of the dressing components was carried out using an ultrasonic disperser without adding emulsifiers. The dynamics of accelerated oxidation of the oil base of products at 60 °C was studied. It was proved that most types of vinegar (in particular, white and red wine, pomegranate, apple) do not affect the oxidation processes of the oil-vinegar

dressing. It was found that the components of olive vinegar obtained by fermentation of wastewater from olive oil production, as well as the components of alcohol vinegar extract from olive leaves, exhibit antioxidant activity. In the study, the question of a balanced ratio of ω -3: ω -6 PUFA in the oil fraction remains unresolved, as it is irrational in the dressing and amounts to 1:10. The issue of enriching the oil component of the dressing with essential ω -3 PUFA is partially resolved in [10], where a dressing recipe based on avocado fruits enriched with PUFA was developed. The influence of the amount of dressing components was evaluated:

- avocado (40, 60, 80 %);
- whey protein (3.0; 6.5; 10 %).

The impact was assessed on quality indicators such as:

- total amount of soluble substances;
- viscosity;
- peroxide value of the oil fraction;
- emulsion stability;
- organoleptic indicators;
- microbiological stability.

It was proved that the formulation including 64.0 % avocado and 8.0 % whey protein is an optimal composition with the following quality indicators:

- the highest total content of soluble solids (34.62 %);
- viscosity (11245 cP);
- emulsion stability (99.84 %);
- positive organoleptic and microbiological indicators.

Whey protein mixed with avocado was found to increase total soluble solids, resulting in high pseudo-plasticity of the product. In the composition of the oil base of the avocado dressing, the fatty acid composition had the following characteristics:

- oleic acid – 55.20 %;
- palmitic acid – 22.73 %;
- linoleic acid – 10.77 %;
- palmitoleic acid – 9.28 %;
- α -linolenic acid – 1.72 %.

Avocado dressing was proved to be a source of ω -6 and ω -3 PUFA (the ω -3: ω -6 ratio is 1.0:6.3) and is used to increase the nutritional value of products. But in [9, 10], the issue of stabilization of the lipid base with an oxidation-labile component – α -linolenic PUFA against oxidative damage remains unresolved. This issue was partially resolved by scientists in [11–14].

The authors of the study [11] found the possibility of increasing the oxidative stability of the oil base of the dressing based on olive oil by adding Spanish plum leaf extract to the formulation. Spanish plum leaves were extracted with water (leaf:water ratio 1:10 weight/volume) at room temperature. The main phenolic compounds of the extract were gallic acid, epigallocatechin, catechin and galocatechin. Different concentrations of the extract (0, 200, 400, 800, 1,600 ppm) were added to the dressing samples. It was determined that the investigated samples of the dressing with plum leaf extract did not show any changes in the emulsion stability index after 4 weeks of storage at 4 °C. It is noted that the oxidative stability of the oil base of the dressing increased with an increase in the concentration of plum leaf extract. It is worth noting that obtaining Spanish plum extract in the production of dressing requires additional equipment, which in some way increases the cost of the process. Also of interest is the inhibition of microbiological processes in dressings with the addition of aqueous plant extracts obtained at sufficiently high extraction temperatures.

In particular, the issue of microbiological spoilage of dressings due to the multiplication of *Zygosaccharomyces parabailii* microorganisms owing to the resistance of this microorganism to osmotic pressure was investigated in [12]. The effect of organic acids and storage temperatures (4, 10, 25 °C) on the growth of *Z. parabailii* and the functional and technological properties of the dressing was considered. To acidify the dressing, acetic, lactic and gluconic acids were used separately and in combination. Dressings contaminated with *Z. parabailii* and containing only acetic acid were found to generally have lower amounts of *Z. parabailii* compared to samples contaminated with *Z. parabailii* containing combinations of acids other than acetic acid. In general, product storage temperature had the greatest effect on the growth of *Z. parabailii* for 45 days of storage. It was determined that the type and combination of acidifiers affect the mechanical properties of model dressing samples. During the 45-day storage period, all samples showed increased viscosity and viscoelastic behavior with dominant elasticity. The degree of change in the rheological behavior of the model product samples over time was ambiguous and depended on the type of acid used in the formulation. Thus, the question of finding dressing components that would have a complex antioxidant and preservative effect on finished products is of interest.

The problem of dressing stabilization against microbiological and oxidative spoilage was solved in [13]. The use of an extract of phenolic compounds of olive leaves as an additive to the dressing, which has antioxidant and antimicrobial activity, is substantiated. The antioxidant effect of encapsulated (*e-Ole*) and free olive leaf extract (*f-Ole*) on the oxidative and microbiological stability of dressings during storage was compared. The products were two-component emulsion systems, the quality indicators of which were monitored for 90 days at 4 °C. The study of the microstructure of the emulsions proved a more uniform droplet size distribution with the inclusion of *f-Ole*. Enrichment of the dressing with *f-Ole* increased the induction period of oil fraction oxidation from 18–20 days to 50 days. Encapsulation of *e-Ole* by emulsification–internal gelation was found to be effective for the gradual release of polyphenols during storage of the dressing, thus increasing the antioxidant and preservative effects of the olive leaf extract. It should also be noted that the proposed development requires the introduction of an additional technological operation in production, which is not always positively perceived by the manufacturer.

An attempt to increase the oxidative and thermal stability of the oil base for dressing was made in [14]. The study analyzed the samples obtained by adding black pepper and ginger essential oils to refined coconut oil (*CNO*) in concentrations of 0.1 and 1.0 % (*CNOP-0.1*; *CNOP-1.0*; *CNOG-0.1*; *CNOG-1.0*). The stability of the oils was evaluated by the content of free fatty acids, peroxides, conjugated dienes and trienes and compared to *CNO* without any additives, as well as to a reference sample (*CNO* with the synthetic antioxidant tertiary butylhydroquinone (*CNOT*)). The stability of *CNOP-1.0* and *CNOG-1.0* was found to be almost the same as that of *CNOT*. The possibility of using flavored oil as a table salad oil was investigated by adding it to a vegetable salad and was found to be more acceptable by sensory evaluation than the reference sample (*CNOT*). The question of how the antioxidant activity of the studied essential oils changes in liquid oils, where the PUFA content is much higher than in coconut oil, remained unsolved in the study.

An alternative method for increasing the oxidative stability of the oil base of the dressing was developed in [15]. The technology of spray-dried powders for cholesterol-free dressings using a mixture of mono- and diglycerides (*MG–DG*) as an emulsifier is proposed. Optimal conditions for the enzymatic synthesis of *MG–DG* from rice bran oil (*RBO*) and glycerol (*Gly*) using *Candida antarctica* lipase were studied. The synthesis was carried out by glycerololysis of purified *RBO* and *Gly* at molar ratios of 2:1, 2.5:1 and 3:1 (*Gly* to *RBO*) and enzyme concentrations of 2 % and 5 %. The highest yield of *MG* and *DG* (0.54 ± 0.01 and $0.49.03 \pm 0.01$ mg/ml) was obtained in the sample prepared using a 2:1 molar ratio and 5 % enzyme concentration, and this sample is considered optimal. The dressing oil base containing 0.5 % *MG–DG* spray-dried at 170 °C was found to have the highest powder yield (42.70 %), solubility (98.04 %) and stability to oxidative spoilage (100 %). This development demonstrates the feasibility of preparing oil-containing powders for spray-dried dressings with the synthesized *MG–DG* emulsifying complex. It should be noted that such development takes place only under the condition of processing lipid-containing raw materials with the majority of saturated fatty acids, which are quite stable to oxidative spoilage even under extreme conditions.

There is a need to expand scientific data on the development of oxidation-stable dressings with high nutritional value, enriched with ω -3 PUFA with a ω -3: ω -6 PUFA ratio of less than 1:5. Such developments will make it possible to obtain products with pronounced health-improving properties that can compete in terms of shelf life with analogs of traditional composition. That is, in addition to solving the problem of enriching the dressing with oxidation-labile essential components, the shortage of which is observed all over the world [3, 16], it is possible to extend the shelf life of such products.

In view of the above, it is appropriate to conduct a study devoted to increasing the nutritional value of the dressing by using a source of ω -3 PUFA in its composition – cold-pressed linseed oil and its blending with oils with a high content of natural antioxidants. This will increase the stability to oxidative spoilage of the created oil base of the dressing, which is valuable from a physiological point of view.

3. The aim and objectives of the study

The aim of the study is to develop the composition of an oxidation-stable dressing with high nutritional value. The obtained results of the work will make it possible to expand the range of dressings based on unrefined first cold-pressed oils, which are enriched with PUFA of the ω -3 group and at the same time are stable to oxidation.

To achieve the aim, the following objectives were accomplished:

- to study the physico-chemical indicators, vitamin and fatty acid composition of the selected unrefined first cold-pressed oils as an oil base for the dressing – linseed, corn and sesame;
- to justify the range of rational ratios of the selected oils in the blend according to the ω -3: ω -6 PUFA ratio and stability to oxidative spoilage;
- to study the organoleptic and physico-chemical parameters of the finished product – oxidation-stable dressing with high nutritional value based on the developed oil mixture.

4. Materials and methods of the study

4.1. Object and hypothesis of the study

The object of the study is the composition of the oil base of an oxidation-stable dressing with high nutritional value.

The main hypotheses of the study are:

- the possibility of increasing the nutritional value of the dressing by using first cold-pressed oil with a high content of ω -3 PUFA (linseed oil) as part of the oil base;
- the possibility of extending the shelf life of the dressing enriched with ω -3 PUFA by blending with unrefined first cold-pressed oils with a high content of antioxidants sesamol (sesame oil) and tocopherols (corn oil).

The study assumes that the induction period of accelerated oxidation of samples of oils and oil compositions is proportional to their induction period of oxidation under the recommended storage conditions (in the absence of light access from 0 °C to +20 °C).

The following simplifications are adopted in the study:

- the influence of carotenoids present in oils on inhibiting the processes of oxidative spoilage of unrefined oils and blends based on them is not taken into account;
- freshly produced samples of unrefined first cold-pressed oils from different manufacturers have almost identical parameters of fatty acid composition, antioxidant composition, as well as physico-chemical indicators and have similar oxidation stability.

4.2. Studied materials used in the experiment

The following materials were used in the study:

- unrefined first cold-pressed linseed oil (produced in Ukraine), according to CAS 8001-26-1;
- unrefined first cold-pressed corn oil (produced in Ukraine), according to CAS 8001-30-7;
- unrefined first cold-pressed sesame oil (produced in Ukraine), according to CAS 8008-74-0;
- unrefined first cold-pressed sunflower oil (produced in Ukraine), according to CAS 8001-21-6;
- acetic acid (concentration 9 %, produced in Ukraine), according to CAS 64-19-7;
- sugar (produced in Ukraine), according to CAS 57-50-1;
- salt (produced in Ukraine), according to CAS 7647-14-5;
- garlic powder (produced in China), according to CAS 539-86-6;
- xanthan gum (produced in China), according to CAS 11138-66-2;
- potassium sorbate (produced in China), according to CAS 24634-61-5.

4.3. Methods of studying the quality indicators of unrefined first cold-pressed oils

The color value of oil samples was determined on the iodine scale according to DSTU 4568. The mass fraction of moisture and volatile substances in oils was determined gravimetrically according to DSTU 4603. The mass fraction of phosphorus-containing substances in oils was determined by the colorimetric method according to DSTU 7082. The acid and peroxide values of oils were determined by the titrimetric method according to DSTU ISO 660 and DSTU ISO 3960. The content of waxy substances in oils was determined by the “cold test” method according to DSTU 4492. The content of tocopherol in the samples of the studied oils was determined by high-performance liquid chromatography according to DSTU EN ISO 9936. The content of sesamol and

sesamol was determined by the colorimetric method. The fatty acid composition of oil samples was determined by the chromatographic method according to DSTU ISO 5508 on a Shimadzu chromatograph (Japan).

4.4. Method of studying the induction period of accelerated oxidation of unrefined first cold-pressed oils and their blends

The induction period of accelerated oxidation of oils and their blends was carried out by an accelerated method according to DSTU ISO 6886. The principle of the method is based on the exposure of oil samples, through the volume of which air is bubbled, at a constant elevated temperature (80 ± 1 °C). Samples are periodically taken, in which the content of primary oxidation products (peroxide value) is determined. The induction period of the oil samples is determined graphically by the dynamics of the increase in the peroxide value.

4.5. Method of obtaining model dressing samples

The dressing is prepared at room temperature as follows. Prepared unrefined first cold-pressed oils are mixed to create a blend. Sugar, salt, potassium sorbate, acetic acid (concentration 9 %), and xanthan gum are successively dissolved in the prepared water. Then, garlic powder and oil blend are gradually added with thorough mixing, the system is subjected to homogenization (speed not less than 1,000 rpm) for 5 minutes.

4.6. Methods of determining the organoleptic and physicochemical indicators of the developed dressing

Organoleptic indicators (color, aroma, taste, consistency, texture), titratable acidity, stability of the dressing emulsion were determined according to DSTU 4487. The dry matter content in the dressing was determined according to DSTU 7804. The acid and peroxide values of the oil fraction of the dressing were determined according to DSTU ISO 660 and DSTU ISO 3960. The oil fraction of the dressing was extracted by the extraction method.

4.7. Research planning and statistical processing of results

To determine the dependence of the ω -3: ω -6 PUFA ratio (1) and the induction period of accelerated oxidation (2) of the blend of oils on their ratio, the method of multivariate regression with the construction of a response surface by the method of a full factorial experiment was chosen. Statistical methods were used for data processing using the Stat Soft Statistica v 6.0 software package (USA). Statistical models of the specified dependencies (1) and (2) were determined by approximating the experimental results using the construction of a trend line. The studies were performed three times. The significance test of the coefficients of the equation of approximation dependencies (1) and (2) was determined by the least squares method. The completeness of the effect of the ratio of oils in the blend on the ω -3: ω -6 PUFA ratio (1) and induction period of accelerated oxidation of the blend (2) was assessed using the coefficient of determination R^2 . The values of $R^2=0.993$ for the equation of dependence (1) and $R^2=0.946$ for the equation of dependence (2) prove the high influence of variations in the ratio of oils in the blend on variations in the ω -3: ω -6 PUFA ratio and induction periods of accelerated oxidation. The significance of the equations of dependencies (1) and (2) was determined by calculating the Fisher's test. The calculated values of the Fisher's test $F_1(3, 6)=18.527$ and $F_2(3, 6)=12.615$ are greater than its

critical table value $F_{table}(3, 6)=4.76$ at the significance level $p=0.05$. Therefore, the obtained results allow us with a probability of 95 % to recognize the values of the coefficients of determination $R^2=0.993$ for dependence (1) and $R^2=0.946$ for dependence (2) as significant, and the equations of approximation dependencies (1) and (2) as significant.

5. Results of studies on the development of an oxidation-stable dressing with high nutritional value

5.1. Study of the physicochemical indicators, vitamin and fatty acid composition of the selected unrefined oils

The components for the oxidation-stable dressing with high nutritional value were substantiated:

- unrefined first cold-pressed oil, characterized by a high content of ω -3 PUFA (linseed oil);
- unrefined first cold-pressed oils of the ω -6 group, characterized by a high content of antioxidants tocopherols (corn) and sesamol and its derivatives (sesame).

It is worth noting that there is a proven non-additive interaction between the antioxidants tocopherols and sesamol [3]. The results of the study of the physico-chemical parameters of the selected oils are presented in Table 1.

Table 1

Physico-chemical parameters of samples of unrefined first cold-pressed oils for the oil base of the dressing

Physico-chemical parameters	Studied samples of first cold-pressed oils		
	Linseed	Corn	Sesame
Color value, mg of iodine	33.0±1.0	15.0±0.5	24.0±0.7
Mass fraction of moisture and volatile substances, %	0.040±0.001	0.030±0.001	0.030±0.001
Mass fraction of phosphorus-containing substances, % in terms of stearoolecithin	0.060±0.002	0.040±0.001	0.050±0.002
Acid value, mg KOH/g	0.80±0.02	0.30±0.01	0.30±0.01
Peroxide value, mmol ½O/kg	1.60±0.05	1.10±0.03	1.80±0.05
Content of waxy substances	No		

The results of determining the content of tocopherol isomers, sesamol and its derivatives in samples of the selected unrefined first cold-pressed oils are given in Table 2.

Table 2

Antioxidant content in samples of unrefined first cold-pressed oils for the oil base of the dressing

Antioxidants	Studied samples of first cold-pressed oils		
	Linseed	Corn	Sesame
Amount of tocopherols, mg/l, of which:	1032.0±42.0	7160.0±286.0	930.0±38.0
α-tocopherol	354.0±13.0	3520.0±140.0	318.0±12.0
β-tocopherol	277.0±11.0	3025.0±121.0	249.0±10.0
γ-tocopherol	363.0±15.0	530.0±22.0	331.0±14.0
δ-tocopherol	38.0±1.5	81.0±3.1	57.6±1.3
Sesamol, %	-	-	0.415±0.013
Sesamolin, %	-	-	1.24±0.04

The results of determining the fatty acid composition of samples of the selected unrefined first cold-pressed oils are given in Table 3.

Table 3

Fatty acid composition of samples of unrefined first cold-pressed oils for the oil base of the dressing

Fatty acids	Content of first cold-pressed oils % of the total amount		
	Linseed	Corn	Sesame
C _{14:0}	0.050±0.001	0.000	0.000
C _{16:0}	5.400±0.160	12.100±0.360	8.000±0.250
C _{16:1}	0.000	0.240±0.007	0.000
C _{18:0}	3.800±0.110	2.210±0.065	5.800±0.175
C _{18:1}	19.800±0.59	31.300±0.932	37.400±1.120
C _{18:2}	14.100±0.420	52.200±1.570	47.700±1.430
C _{18:3n3}	56.500±1.700	1.400±0.042	0.700±0.021
C _{18:3n6}	0.000	0.000	0.000
C _{20:0}	0.100±0.003	0.300±0.009	0.400±0.012
C _{20:1}	0.100±0.003	0.100±0.003	0.000
C _{22:0}	0.150±0.004	0.150±0.0340	0.000
C _{24:0}	0.000	0.000	0.000
ω-3:ω-6	4.00	0.03	0.01
Total	100.000	100.000	100.000

The obtained results show that the samples of the selected unrefined first cold-pressed oils practically do not differ in physico-chemical parameters (Table 1). There are differences in the antioxidant composition of oils, in particular in the isomeric composition of tocopherols of linseed, corn and sesame oils (Table 2). The amount of tocopherols in the samples of unrefined first cold-pressed oils is different:

- linseed oil - 1032.0±42.0 mg/l;
- corn oil - 7160.0±286.0 mg/l;
- sesame oil - 930.0±38.0 mg/l.

The content of specific antioxidants of unrefined first cold-pressed sesame oil is:

- sesamol - 0.415±0.013 %;
- sesamolin - 1.24±0.04 %.

The obtained data on the composition of the given oils of the specified degree of processing meet the requirements of the relevant regulatory documentation (CAS 8001-26-1, CAS 8001-30-7, CAS 8008-74-0).

5.2. Justification of the range of rational ratios of the selected oils

The features of the fatty acid composition, as well as the oxidative stability of the blend of the selected unrefined first cold-pressed oils with concentrations from 0 to 100 % were investigated. Namely, the ω-3:ω-6 PUFA ratio and the induction period of accelerated oxidation were determined. The content of the studied oils in the blend was varied in steps of 25.0 %. The calculated values of the ω-3:ω-6 PUFA ratio in the blend were within 0.01...4.00. Experimentally determined induction periods of accelerated oxidation of blend samples were within 0.6...4.5 hours.

Equation (1) presents the statistical dependence of the ω-3:ω-6 PUFA ratio of the blend of the selected oils ($P(c_b, c_c, c_s)$, units) on the ratio of components:

- linseed oil (c_b , mass fraction);
- corn oil (c_c , mass fraction);
- sesame oil (c_s , mass fraction);

$$R(c_b, c_c, c_s) = 3.0224 \cdot c_l - 0.2361 \cdot c_c - 0.2225 \cdot c_s \tag{1}$$

The graph of the obtained dependence is shown in Fig. 1.

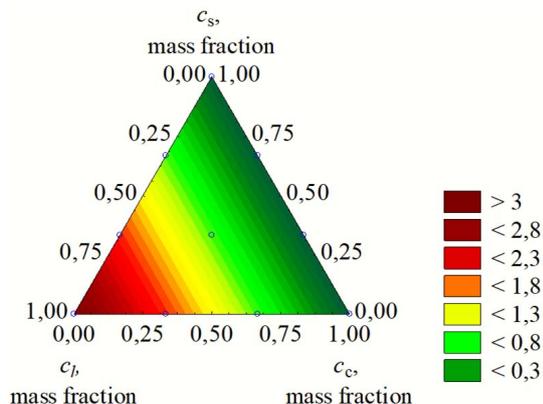


Fig. 1. Dependence of the ω-3:ω-6 PUFA ratio of the blend of unrefined first cold-pressed linseed, corn and sesame oils on their ratio

Equation (2) shows the statistical dependence of the value of the induction period of accelerated oxidation of the blend of the selected oils ($PI(c_b, c_c, c_s)$, hours) on the ratio of components:

- linseed oil (c_l , mass fraction);
- corn oil (c_c , mass fraction);
- sesame oil (c_s , mass fraction);

$$PI(c_b, c_c, c_s) = 0.6 \cdot c_l + 5.4 \cdot c_c + 14.5 \cdot c_s - 5.85 \cdot c_l c_c - 4.275 \cdot c_l c_s + 7.425 \cdot c_c c_s + 4.05 \cdot c_l c_c (c_l - c_c) + 9.675 \cdot c_l c_s (c_l - c_s) + 8.325 \cdot c_c c_s (c_c - c_s) - 76.5 \cdot c_l c_c c_s \tag{1}$$

The graph of the obtained dependence is shown in Fig. 2.

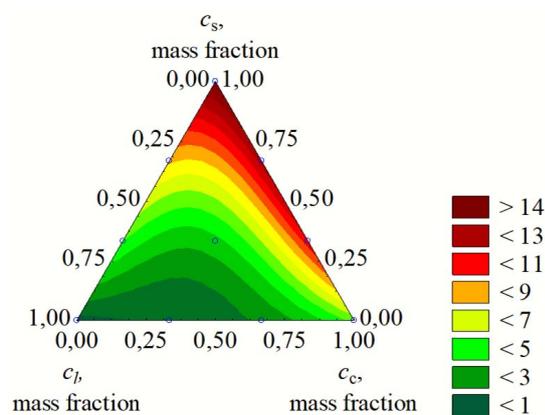


Fig. 2. Dependence of the induction period of accelerated oxidation of the blend of unrefined first cold-pressed linseed, corn and sesame oils on their ratio

Based on the results of experiments, a range of rational ratios of the selected unrefined first cold-pressed oils in the blend is proposed. In the specified range of oil ratios, the blend has a fatty acid composition characterized by the ω-3:ω-6 PUFA ratio at the level of 0.5 units (i. e. ω-3:ω-6=1:2). In addition, the blend simultaneously has a satisfactory stability to oxidative spoilage (at the level of the value of the induction period of accelerated oxidation of 3.0...4.5 hours), namely:

- linseed oil content - 25±1 %;
- corn oil content - 10...25 %;
- sesame oil content - 25...65 %.

Given the high cost of sesame oil (\$16/l) [17] compared to other components of the blend - corn (\$2.3/l) [18] and linseed (\$3.75/l) [19] oils, it was decided to reduce its content to the minimum possible in the given range:

- linseed oil content - 25±1 %;
- corn oil content - 50±3 %;
- sesame oil content - 25±1 %.

The consumer properties of blended oil of the proposed composition are as follows:

- the ω-3:ω-6 PUFA ratio - 0.58 units (i. e. ω-3:ω-6=1.0:1.7);
- the induction period of accelerated oxidation - 4.1 hours, i. e. 6.8 times more than that in the unrefined first cold-pressed linseed oil sample and 1.3 times less than that in the unrefined first cold-pressed corn oil sample.

It should be noted that an increase in the content of linseed oil in the blend by more than 30±2 % leads to a deterioration of the blend taste (tart with a herbal hint), this reduces the organoleptic characteristics of the blend.

5. 3. Study of the organoleptic and physico-chemical indicators of the developed dressing

A model sample of the dressing of the composition given in Table 4 was produced.

Table 4

Composition of the oxidation-stable dressing with high nutritional value

Name of the component	Content, %
Blend of unrefined first cold-pressed oils, of which:	50.0
Linseed	17.5
Corn	35.0
Sesame	17.5
Acetic acid solution (concentration 9 %)	20.0
Water	20.0
Sugar	5.0
Salt	2.0
Garlic powder	2.4
Xanthan gum	0.5
Potassium sorbate	0.1

The organoleptic and physico-chemical parameters of the model dressing sample on the day of production and after 30 days of storage at a temperature of 8±1 °C were studied.

The product is stable, moderately thick, without signs of separation of components, without films on the surface, has a harmonious aroma of unrefined oils with garlic notes. The dressing taste is balanced, slightly salty, moderately sour, without foreign uncharacteristic flavors, the color is light beige, corresponding to the color of the incoming ingredients, the texture is smooth, the product is easily distributed over salad components. After 30 days of storage under the specified conditions, the product retains its organoleptic indicators.

The obtained results of determining the physico-chemical parameters of the dressing are shown in Table 5.

The stability of the dressing emulsion of the developed composition is 99.0 %. After 30 days of storage under the specified conditions, the stability of the emulsion decreased slightly and amounted to 98 %, which is allowed by the requirements of the relevant regulatory documentation [20].

Table 5

Physico-chemical parameters of the oxidation-stabledressing with high nutritional value compared to the comparison sample

Physico-chemical parameters	Storage period, days	
	After production (0 days)	30 days of storage
Titratable acidity in terms of acetic acid, %	0.72±0.02	0.73±0.02
Dry matter content, %	42.6±1.3	42.8±1.3
Acid value of the oil fraction, mg KOH/g	0.40±0.01	0.70±0.02
Peroxide value of the oil fraction, mmol ½ O ₂ /kg	1.40±0.04	1.60±0.05

6. Discussion of the results of the development of an oxidation-stable dressing with high nutritional value

The physico-chemical parameters, vitamin and fatty acid composition of oil raw materials for oxidation-stable dressing with high nutritional value (unrefined first cold-pressed linseed, corn and sesame oils) were studied, namely:

- color value (Table 1);
- mass fraction of moisture and volatile substances, % (Table 1);
- mass fraction of phosphorus-containing substances, % in terms of steorooleocithin (Table 1);
- acid value, mg KOH/g (Table 1);
- peroxide value, mmol ½O/kg (Table 1);
- content of waxy substances (Table 1).

The content of antioxidants, in particular, tocopherol isomers and sesamol and its derivatives (specific antioxidants of sesame oil) was also investigated (Table 2). The fatty acid composition of the selected oil samples was determined (Table 3). It was found that the samples of these unrefined first cold-pressed oils according to the specified indicators (Table 1–3) meet the requirements of regulatory documentation (CAS 8001-26-1; CAS 8001-30-7; CAS 8008-74-0). The obtained results are explained by the fact that the selected samples are natural and were produced from 1 to 2 months ago. The time since their extraction from the oil raw material did not affect their quality indicators and nutritional value.

The ω -3: ω -6 PUFA ratio, as well as the induction period of accelerated oxidation of the blend of the selected unrefined first cold-pressed oils with component ratios from 0 to 100 % were determined (Fig. 1, 2, equations (1) and (2)). It is proved (Fig. 1, equation (1)) that the given ω -3: ω -6 PUFA ratio as 1:2 lies in the range of linseed oil content in the mixture at the level of 25±1 % and any ratio of other components of the blend. The obtained data are explained by the specifics of the fatty acid composition of the selected oils (Table 3). Linseed oil is a source of ω -3 PUFA (the content of α -linolenic PUFA is 56.500±1.700 % of the total amount of fatty acids). α -linolenic PUFA is almost absent in corn and sesame oils (Table 3). Regarding ω -6 PUFA, its content in corn and sesame oils is quite high and varies slightly (52.200±1.570 and 47.700±1.430, respectively) (Table 3).

The obtained graphical and approximation statistical dependences (Fig. 2, equation (2)) show that an increase in the content of sesame oil in the blend leads to an increase in the oxidative stability of the oil mixture. The obtained data are explained by the specifics of the antioxidant composition of sesame oil (Table 2). Sesame oil is a source of phenolic

antioxidants – sesamol and its derivatives (in particular, sesamolol), which have a powerful effect in inhibiting free radical lipidoxidation [3]. The induction period of accelerated oxidation of unrefined first cold-pressed sesame oil is 14.5 hours compared to that of linseed oil of the same degree of processing – 0.6 hours and corn oil – 5.4 hours.

The rational ratio of linseed, corn and sesame oils in the dressing base is justified, which is 1:2:1, respectively. This ratio is based on the following data:

- linear dependence of the ω -3: ω -6 PUFA blend ratio (1);
- quadratic dependence of the induction period of accelerated oxidation of the blend on the ratio of components (2);
- cost characteristics of raw materials [17–19].

A model sample of dressing based on the oil blend of reasonable composition was produced (Table 4). It was proved that according to organoleptic parameters, the product meets the requirements of the relevant regulatory documentation [20]. The obtained data are explained by a justified ratio of the main raw materials and food additives to create a given structure (xanthan gum) and taste (acetic acid, sugar, salt, garlic powder). In order to inhibit microbiological spoilage, the potassium sorbate preservative is added to the dressing composition at the recommended concentration of 0.1 %. In addition, it was proved that during storage of the model dressing sample for 30 days, its physico-chemical parameters (titratable acidity, dry matter content, acid and peroxide values of the oil fraction) practically do not change (Table 5). The obtained results are explained by the inhibition of chemical (oxidative) and microbiological spoilage processes due to the stabilization of PUFA of the oil component by an antioxidant complex (sesamol, sesamin, tocopherols), as well as the preservative content, respectively.

The results of the conducted studies make it possible to substantiate the development of the composition of an oxidation-stable dressing with high nutritional value. In addition, the obtained data (equations (1) and (2)) can be applied in the development of other ratios of the studied oils, which will have different ω -3: ω -6 PUFA ratios and stability to oxidative spoilage. Such blends of unrefined first cold-pressed oils can be used not only as bases for dressings, but also as oxidation-stable salad oils with high nutritional value. It should be noted that the results of studies can be applied under the condition of using raw materials with high quality indicators. In particular, unrefined linseed oil, in the absence of stabilization mechanisms against oxidative spoilage, has a rather limited shelf life (about 4–6 months) [19].

The scope of application of the results of studies on the development of an oxidation-stable dressing with high nutritional value is the food industry, in particular, the oil and fat industry. The effect of using the results of these studies is the expansion of the range of oil-containing products, in particular dressings enriched with valuable ω -3 PUFA and at the same time stable to oxidation due to natural components.

The results of the study differ from the results of the work [9] in that an oil-vinegar dressing has been developed, which is a stabilized emulsion using xanthan gum. This makes it possible to increase the organoleptic and consumer properties of the dressing, in particular, the uniformity of taste and ease of use. Also, the development differs from the studies [10, 11, 14] by a significantly higher content of α -linolenic PUFA (14.2 % vs. 1.72 % and 0.65 %, respectively), as well as by the proven effect of using a natural antioxidant complex – sesamol, sesamolol and tocopherol isomers. Based on the results of the studies [12, 13], the developed dressing

contains acetic acid as a component with a proven highest preservative effect compared to other food acids (lactic, gluconic). But according to the nutritional value of the oil component of the developed product (ω -3 PUFA, antioxidant complex), it is stabilized not only against microbial spoilage, but also from oxidative spoilage. In addition, in this study, in contrast to [15], the possibility of stabilization of the labile component against oxidative spoilage without using additional equipment (spray dryer), which complicates the technology and makes the finished products more expensive, was proven. In addition, the specified equipment is not appropriate for processing such a thermolabile dressing component as α -linolenic PUFA. Thus, the development of the composition of an oxidation-stable dressing with high nutritional value is interesting from both a scientific and a practical point of view. The results of the studies (Fig. 1, 2 and approximation dependences (1) and (2)) allow us to visualize the dependences of the ω -3: ω -6 PUFA ratio and the induction period of accelerated oxidation of the blend of unrefined first cold-pressed linseed, corn and sesame oils on their ratio. The obtained data were used to substantiate the rational ratio of oils in the dressing blend (Table 4).

The limitation of using the results of the study (in particular, Table 1, 2, 4, 5, Fig. 2, equation (2)) is that unrefined oils were studied that, due to the high content of odorants, are used in a limited range of food products. As an option to overcome this limitation, it is possible to use the corresponding oils in a refined state, the characteristics of which described in Table 3, Fig. 1, dependencies (1) will practically not change.

The disadvantage of the conducted studies is the lack of data on the shelf life of the developed dressing over a longer period of time. It should be noted that the shelf life of oil-containing dressings containing the concentration of preservatives regulated by regulatory requirements is directly proportional to the induction period of accelerated oxidation of the oil component. According to this fact, it is possible to predict the shelf life of the developed dressing, taking into account the stability of the developed oil blend to oxidative spoilage (Fig. 2, equation (2)).

Promising areas of research are:

- study of the shelf life of the oxidation-stable dressing of the developed composition with high nutritional value under recommended storage conditions (temperature $t=0...18$ °C, air humidity ≤ 75 %);

- expansion of the range of dressings with high nutritional value, with an oxidation-stable oil base, using other non-traditional oils with high nutritional and physiological value.

7. Conclusions

1. The physico-chemical parameters, as well as the vitamin and fatty acid composition of unrefined first cold-pressed linseed, corn, and sesame oils as raw materials for dressings, were studied. The specified characteristics of the selected oil samples meet the requirements of regulatory documentation (CAS 8001-26-1, CAS 8001-30-7, CAS 8008-74-0). The source of nutritionally valuable α -linolenic PUFA (ω -3 group) is unrefined linseed oil. The source of antioxidants tocopherols is unrefined corn oil, sesamol and sesamin – unrefined sesame oil.

2. The range of rational ratios of the selected oils in the blend based on the ω -3: ω -6 PUFA ratio as 1:2 and stability to oxidative spoilage is substantiated. The composition of the oil base of the oxidation-stable dressing with high nutritional value, containing unrefined first cold-pressed linseed, corn and sesame oils, respectively 1:2:1, is proposed.

3. It was proved that the organoleptic and physico-chemical indicators of the oxidation-stable dressing with high nutritional value based on the developed oil blend meet the requirements of valid regulatory documentation both on the day of production and during 30 days of storage. The dressing includes a blend of oils (50 %), acetic acid solution (concentration 9 %) (20 %), sugar (5 %), salt (2 %), garlic powder (2.4 %), xanthan gum (0.5 %), potassium sorbate (0.1 %).

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, whether financial, personal, authorship or otherwise, that could affect the study and its results presented in this paper.

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The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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