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DEVELOPMENT OF A FLAVORED OIL COMPOSITION BASED ON HEMP OIL WITH INCREASED RESISTANCE TO OXIDATION

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The way to solve the problem of stabilizing hemp oil against oxidative deterioration while preserving its nutritional value is considered. The peculiarity of the work consists in the development of a flavored oil composition based on hemp oil, which has a high resistance to oxidation. The object of the study is the indicators of the composition and the period of induction of accelerated oxidation of refined hemp and corn oils depending on their ratio and the content of antioxidants (essential oils of coriander, basil and thyme) in the oil composition. A rational ratio of hemp and corn oils in the oil composition of 6:4, respectively, was determined. The consumer properties of this mixture are: the induction period of accelerated oxidation – 4.0 hours, the content of α-linolenic fatty acid – 10.6 % of the total amount of fatty acids. The ratio of essential oils of thyme, coriander, and basil in the complex was determined, with the addition of which the period of induction of accelerated oxidation of the flavored oil composition exceeds that of the original one by 3.75 times. A feature of the obtained results is the possibility of increasing the shelf life of the flavored oil composition based on hemp oil, which allows expanding the range of its consumer properties. From a practical point of view, the development allows you to increase the shelf life and receive additional income from the sale of new, high-quality, competitive products for health-improving use. An applied aspect of using the scientific result is the possibility of creating a range of salad oil compositions based on valuable hemp oil with different organoleptic indicators depending on the ratio of the components of the complex of essential oils

Keywords: hemp oil, corn oil, antioxidants, essential oils, induction period of accelerated oxidation

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1. Introduction

One of the main problems in the structure of nutrition is the imbalance in the composition of fat-containing products [1, 2]. The population consumes sufficient amounts of fats in which polyunsaturated fatty acids of the ω-6 group (sunflower, corn, soybean oil) or monounsaturated ω-9 group (olive oil) prevail. At the same time, there is an acute deficiency of polyunsaturated fatty acids of the ω-3 group in the diet. Disruption in the structure of the population's diet, including an unbalanced intake of ω-3 polyunsaturated fatty acids, contributes to an increase in alimentary diseases (obesity), cardiovascular diseases, diabetes, etc. [3].

A promising source of ω-3 polyunsaturated fatty acids is hemp seed oil (*Cannabis ruderalis*). Hemp oil is made from seed hemp, which does not contain cannabinoids. This oil is used in medical practice, pharmaceuticals and cosmetology. The use of hemp oil for food purposes is relatively limited due to the small volume of production, although a number of studies have substantiated the positive effect of this oil on health, and the need for nutrition has been proven [4]. The oil content of hemp seeds is a varietal characteristic and is about 27–38 %. Hemp oil contains 54–56 % linoleic (ω-6), 12–16 % linolenic (ω-3) and 16–18 % oleic (ω-9) fatty acids, which are essential and cannot be synthesized in the human body. The benefits of hemp oil are determined by the presence of a high content of polyunsaturated acids, as well as tocopherols, carotenoids, phytosterols and a number of other biologically active compounds. The special value of hemp oil lies in the increased, compared to other vegetable oils, content of unsaturated fatty acids, which reaches 84.9–86.3 %. According to the ratio of the content of ω-3 and ω-6, which are recommended in the prevention and treatment of diseases of the cardiovascular and nervous system, obesity, hemp oil has a ratio of 1:3, which is physiologically valuable [5].

However, the high content of polyunsaturated fatty acids is a limitation for the use of hemp oil during heat treatment and long-term storage. A significant disadvantage of vegetable oils with a high content of ω-3 polyunsaturated fatty acids during production and storage is a high susceptibility to oxidative deterioration. Actually, the process of oxidation of vegetable oils is affected by a large number of conditions, including, in addition to the fatty acid and triacylglycerol composition, the presence of moisture and oxidation products, enzymatic, photo- and thermal processes, the presence of pro-oxidants, in particular metals of variable valence, etc. [6]. Oxidative spoilage of fat-containing products is a problem from a physiological and technological point of view [7, 8]. To overcome the oxidative lability of certain oils, it is advisable to develop blends on the basis of food combinatorics [9] and the use of antioxidants [10]. In order to protect the fat product from oxidation, synthetic inhibitors of peroxide oxidation are widely used. These substances have limited use due to toxicity, besides, they have no biological value [10, 11]. An alternative to synthetic antioxidants is the use of natural plant extracts, which have powerful antioxidant properties, are safe, have a certain biological value and have a synergistic interaction with other ingredients of oil products [6, 12]. The most effective antioxidants are various polyphenols, but there are known studies that show the antioxidant activity of other natural compounds, including terpene compounds that form the basis of essential oils. Due to their natural origin, they are considered non-toxic, safe for humans and the environment, and biodegradable compared to synthetic antioxidants. Therefore, the use of natural antioxidants is more environmentally friendly and acceptable for consumers, for example, as food antioxidants, dietary supplements or functional food ingredients [6]. Therefore, it is urgent to find ways to stabilize the oxidation process of hemp oil through the creation of an oil composition (blend) with oxidation-stable oil, in particular corn oil (a source of natural tocopherol). It is also promising to add antioxidants to oil compositions, which, in addition to inhibiting oxidation, have a positive effect on the organoleptic characteristics of oils (color, smell, taste) [10].

Therefore, research aimed at creating an oil composition based on hemp oil with increased resistance to oxidation due to natural aromatic substances is relevant, as it will allow you:

– to identify the combined effect of the selected oils on the stability to oxidative deterioration and the fatty acid composition of the oil composition,

– to predict the shelf life of this product,

– to expand the range of edible oil compositions based on hemp oil.

The results of scientific research are necessary to expand the range of competitive oil compositions for food purposes based on biologically valuable hemp oil.

2. Literature review and problem statement

In [5], it was noted that hemp oil is extremely susceptible to oxidative destruction, which can be explained by the high content of polyunsaturated fatty acids in the oil. It is indicated that a higher temperature and a longer time of the roasting process have a negative effect on the oxidative stability of the oil. Thus, it is expedient to find ways to stabilize oxidative processes in hemp oil.

This approach was used in [13], which investigated the total content of phenolic compounds in unrefined cold-pressed hemp and milk thistle seed oil. Chlorogenic acid has been proven to inhibit the process of lipid peroxidation in hemp seed and milk thistle oils. It can be noted that it is expedient to study the oxidative stability of oils after refining, because the use of purification from accompanying substances for unconventional oils is expanding.

The authors of the work [14] analyzed the content of phenolic compounds and antioxidant activity of unrefined cold-pressed vegetable oils, including corn, soybean, hemp seed, flax seed, pumpkin seed, canola, grape seed, and rice bran oils. Among the studied oils, corn oil showed the highest antioxidant activity. The oxidative stability of oil compositions based on stable and labile oils, in particular corn and hemp, remains an undefined issue.

In [15], it was found that essential oils exhibit antioxidant activity in a wide range, they are able to inactivate free radicals, form complexes with heavy metal ions, which are pro-oxidants, and thus slow down the process of lipid oxidation. It has been proven that most essential oils should be used not only as food additives to improve the sensory and health-giving properties of food products, but also as natural antioxidants. But issues related to effective concentrations of essential oils in fat products as antioxidants remained unresolved.

This very issue was resolved in [16], which analyzed the chemical composition of clove essential oil (*Eugenia Caryophyllata*) and proved its antioxidant activity in stabilizing lipids against oxidative damage. Its rational concentrations in model fat systems are substantiated. This plant is considered one of the main natural sources of phenolic acids (gallic, ferulic, caffeic, salicylic and ellagic), flavonoids (quercetin, kaempferol and its derivatives), hydroxyphenylpropynes, hydroxycinic and hydroxybenzoic acids [17]. It is advisable to expand the study of the antioxidant effect of other essential oils in fat products.

The work [18] studied the antioxidant properties of aqueous extracts isolated from some plants of the mint family:

field mint (*Méntha arvénsis*) and spearmint (*Méntha spicáta*), basil (Ócimum) and lemon balm (*Melissa officinalis*). The antioxidant activity of extracts from the specified plants is due to the presence of phenolic compounds, which makes them a promising source of antioxidants for the food industry. A model system for the influence of phenolic compounds on the oxidative reactions of fats was linseed oil. It has been proven that basil extract has the most pronounced antioxidant effect, and spearmint extract – the least.

In [19], the composition of essential oils of peppermint (*Mentha piperita*) and spearmint (*Mentha spicata*) was investigated. It was determined that due to the high content of phenolic compounds, both aqueous extracts and essential oils of mint are natural antioxidants. The study determined rational concentrations of aqueous extracts and essential oils of the specified plants in model fat systems for stabilization against oxidative damage. It is worth noting that among the representatives of the *Lamiaceae* family, mint is one of the most popular cultivated aromatic plants [20]. A promising area of research is to determine the combined antioxidant activity of the studied species of mint or their combination with other essential oil raw materials.

This research development is described in [21], where the authors studied the effect of supercritical extracts of mint (*Mentha piperita*) and clove (*Syzygium aromaticum*) on the oxidative stability of model oil systems. It was found that the oxidative stability of the model samples enriched with supercritical extracts of clove and mint was more than twice as high as compared to the control sample (without the addition of supercritical extracts). Accordingly, the non-additive synergistic effect of supercritical extracts of the specified plants on model oil systems was determined. An undefined point in the study is the lack of substantiation of the proposed concentrations and ratios of supercritical extracts in the oil system.

There is a need to expand scientific data on the development of oil compositions based on valuable hemp oil, as well as its stabilization with natural physiologically active antioxidants, in particular essential oils. The antioxidant properties of extracts from plant raw materials and essential oils are due to the presence of a significant amount of phenolic compounds in their composition. To stabilize oils, it is advisable to use essential oils, rather than aqueous extracts, due to their aromatic properties. In addition to solving the issue of increasing the resistance of fats to oxidative deterioration, essential oils will allow you to regulate the taste and aroma properties of salad oils, thus expanding their range. In this regard, a study devoted to identifying the combined effect of essential oils (in particular, coriander, basil, thyme) on the period of induction of accelerated oxidation of an oil composition based on hemp oil should be considered appropriate. This will increase its stability to oxidative deterioration to extend the shelf life and simultaneously preserve physiologically active components, in particular α-linolenic fatty acid.

3. The aim and objectives of the study

The aim of the study is to develop an oil composition based on hemp oil with increased resistance to oxidation due to natural aromatic substances with antioxidant properties. This will make it possible to expand the range of fatty products based on biologically valuable hemp oil.

To achieve the aim, the following objectives were accomplished:

– to investigate the consumer properties of the selected oils for blending – hemp and corn;

– to investigate the combined effect of the content of the selected oils in model samples of the oil composition on its period of induction of accelerated oxidation and the content of polyunsaturated fatty acids of the ω-3 group;

– to investigate the combined effect of essential oils (coriander, basil, thyme) on the induction period of accelerated oxidation of the oil composition of the justified composition.

4. Materials and methods

4. 1. Object and hypothesis

The object of the study is consumer indicators, in particular the composition and period of induction of accelerated oxidation of hemp and corn oils, as well as their composition depending on the ratio and content of essential oils.

The main research hypotheses are:

– the possibility of increasing the oxidation stability of refined hemp oil by creating an oil composition with refined oil having a higher content of natural tocopherols and a lower content of α-linolenic fatty acid;

– the possibility of increasing the stability to oxidation of an oil composition based on hemp oil by using a complex of essential oils due to the synergistic effect of essential oil components as antioxidants of triacylglycerols.

The study assumes that the period of induction of accelerated oxidation of samples of oils and oil compositions is proportional to their periodic induction of oxidation under recommended storage conditions (in the absence of light access from 0 °C to +20 °C [9]).

The following simplifications are adopted in the study:

– the effect of the presence of primary and secondary oxidation products, the content of which meets the requirements of regulatory documentation, on the oxidative stability of oils and oil compositions is not taken into account;

– samples of oils and essential oils from different manufacturers and different batches of production have almost identical physical and chemical parameters and composition characteristics and have the same stability to oxidative deterioration. The purpose of this simplification is to demonstrate the establishment of a certain level of repeatability in studying the effect of the ratio of oils and essential components on the induction period of accelerated oxidation of products.

4. 2. Materials used in the experiment

The following materials were used during the research:

– refined hemp oil (produced in Ukraine), according to CAS 89958-21-4;

– refined corn oil (produced in Ukraine), according to CAS 8001-30-7;

– coriander essential oil (produced in Ukraine), according to CAS 8008-52-4;

– basil essential oil (produced in Ukraine), according to CAS 84775-71-3;

– thyme essential oil (produced in Ukraine), according to CAS 8007-46-3.

4. 3. Methods of studying the consumer properties of the selected oils

The content of moisture and volatile substances is determined by the gravimetric method according to

DSTU 4603. The acid and peroxide values of oils are determined by the titrimetric method according to DSTU ISO 660 and DSTU ISO 3960, respectively. The anisidine value of oils was determined by the photometric method according to DSTU EN ISO 6885. The content of tocopherol isomers in the samples of the studied oils was determined by the high-performance liquid chromatography method according to DSTU EN ISO 9936. The composition and fatty acid content of the oil samples were determined according to DSTU ISO 5508 on a Shimadzu chromatograph (Japan).

4. 4. Method for determining the period of induction of accelerated oxidation of oils and oil compositions

The induction period of accelerated oxidation of oils and oil compositions was determined by the accelerated method of "reactive oxygen" in accordance with DSTU ISO 6886. The principle of the method consists in keeping samples of the studied material at a constant elevated temperature (80±2 °C) and free access of oxygen, mixing and periodic determination of the peroxide value of lipid samples extracted from the samples. The lipid peroxide value characterizes the degree of accumulation of primary oxidation products. The induction period is defined graphically as the period of time after which there was a significant increase in the peroxide value, that is, the concentration of primary oxidation products (peroxides and hydroperoxides).

4. 5. Method for determining the composition of essential oils

The distribution of essential oil components was determined on a chromatograph equipped with a flame ionization detector under the following conditions:

– capillary quartz column (length 30 m, inner diameter 0.32 mm);

– stationary phase – β-cyclodextrin (layer thickness 0.25 μm);

– column temperature 70 ≡C (isotherm for 5 minutes);

– heating rate 3°/min. up to 115 °C (isotherm for 20 min.);

– heating rate 4°/min. up to 200 °C (isotherm for 10 min.) in a flow of nitrogen carrier gas;

– carrier gas velocity (helium, hydrogen) – 30 cm/s;

– flow separation 1:50.

4. 6. Method of obtaining model samples of the flavored oil composition

In view of the preliminary screening studies of the organoleptic characteristics of the finished products, it was decided to introduce essential oils into the developed oil composition in an amount of 0.30±0.01 %. The resulting solutions were subjected to homogenization at a temperature of 22±1 °C at a rate of at least 1,000 rpm. within 5 minutes.

4. 7. Research planning and statistical processing of results

To determine the dependence of the period of induction of accelerated oxidation of the flavored oil composition on the ratio of essential oils, the method of multifactorial regression with the construction of a response surface by the method of a full factorial experiment was chosen. Mathematical methods were used for data processing using the Stat Soft Statistica v 6.0 software package (USA). The statistical model of dependence is determined by approximating the results of experiments by constructing a trend line. The study was performed three times. The significance testing of the coefficients of the approximation dependence equation (1) was determined by the least squares method. The quality of the approximation dependence equation (1) and the completeness of the effect of the ratio of essential oils on the period of induction of accelerated oxidation of the flavored oil composition were evaluated by the coefficient of determination R^2. The obtained value of R^2=0.962 allows us to conclude about the high influence of variations in the ratio of essential oils on variations in the induction period of accelerated oxidation of the flavored oil composition. The significance of the dependence equation (1) was determined by calculating the Fisher test (F), based on the assumption (null hypothesis) that the equation is statistically insignificant. The calculated value of Fisher's test was $F(3, 6)$=18.527.

The calculated value of Fisher's test is greater than its critical table value $F_{tab}(3, 6)$=4.76 at the significance level p=0.05. This result allows us to reject the null hypothesis and, with a probability of 95 %, to recognize the value of the coefficients of determination R^2=0.962 for dependence (1) as significant, and the approximation dependence equation (1) as significant.

5. Results of studies on the development of a composition of a flavored oil composition based on hemp oil

5. 1. Study of the consumer properties of the selected oils for blending

Refined corn oil was chosen as a component of the oil composition based on refined hemp oil. The content of moisture and volatile substances, analytical values characterizing the flow rate of oxidative destruction processes in oils for the oil composition, as well as their periods of induction of accelerated oxidation, were studied (Table 1).

Table 1

Physico-chemical parameters of the samples of the studied oils

Indicators	Studied samples of oils	
	Hemp oil	Corn oil
Mass fraction of moisture and volatile substances, %	0.0500±0.0020	0.0100±0.0005
Acid value, mg KOH/g	0.100±0.005	1.050±0.050
Peroxide value, mmol ½O/kg	0.260±0.010	0.150±0.006
Anisidine value, CU	1.60±0.06	0.90±0.03
Induction period of accelerated oxidation, h.	2.8±0.1	5.5±0.2

The composition of the isomeric fraction of tocopherols and their content in oil samples for the oil composition were determined (Table 2).

Table 2

Content of tocopherol isomers in the samples of the studied oils

Tocopherol isomers	Content in the studied oil samples, mg/l	
	Hemp oil	Corn oil
α-tocopherol	236.0±9.0	3200.0±128.0
β-tocopherol	185.0±7.2	2750.0±110.0
γ-tocopherol	242.0±9.6	485.0±19.2
δ-tocopherol	25.0±1.0	74.0±2.8
Total	688±27.5	6509±260.36

The composition and fatty acid content of the oil samples selected for the study were determined (Table 3).

Table 3

Fatty acid composition of the samples of the studied oils

Name of fatty acids	Content in the studied samples, % of the total amount	
	Hemp oil	Corn oil
Myristic $C_{14:0}$	0.050±0.002	0.100±0.004
Palmitic $C_{16:0}$	6.200±0.230	11.800±0.470
Palmitoleic $C_{16:1}$	0.100±0.004	0.150±0.006
Stearic $C_{18:0}$	3.100±0.120	2.300±0.090
Oleic $C_{18:1}$	16.300±0.650	31.800±1.270
Linoleic $C_{18:2}$	54.500±2.180	51.600±2.060
α-linolenic $C_{18:3n3}$	16.800±0.670	1.200±0.040
γ-linolenic $C_{18:3n6}$	1.300±0.05	0.000
Arachidic $C_{20:0}$	0.800±0.004	0.500±0.020
Gondoic $C_{20:1}$	0.500±0.020	0.3000.010±
Behenic $C_{22:0}$	0.300±0.010	0.1500.006±
Lignoceric $C_{24:0}$	0.100±0.004	0.1000.004±
Total	100.000	100.000

The results of the studies (Tables 1–3) prove that the raw material samples for the oil composition according to the parameters that determine the processes of oxidative destruction (moisture content, analytical values, fatty acid composition) meet the requirements established in the relevant regulatory documentation – CAS 89958-21-4; CAS 8001-30-7.

5. 2. Study of the combined effect of the content of the selected oils in model samples of the composition on its period of induction of accelerated oxidation and the content of polyunsaturated fatty acids of the ω-3 group

The influence of the ratio of hemp and corn oils in the oil composition on the induction period of accelerated oxidation, as well as the content of polyunsaturated fatty acids of the ω-3 group in the oil composition, was determined. The content of hemp and corn oils in the oil composition was varied in the range of 0.0…100.0 % with a step of 10.0 %. The obtained values of the induction period of the accelerated oxidation of the oil composition were within 2.8…5.5 hours; the content of polyunsaturated fatty acids of the ω-3 group – within 1.2…16.8 % of the total amount of fatty acids. Diagrams of the obtained dependencies are presented in Fig. 1, 2.

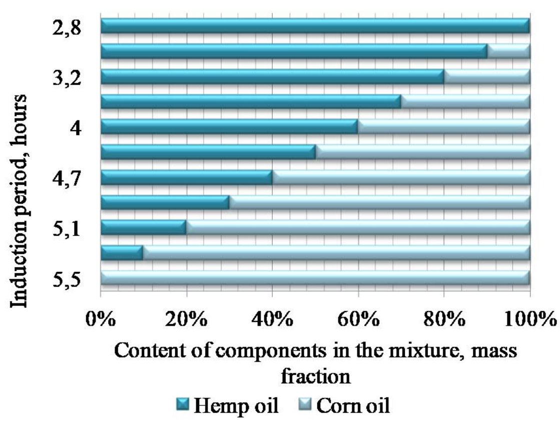

Fig. 1. Dependence of the induction period of accelerated oxidation of the oil composition on the content of hemp and corn oils

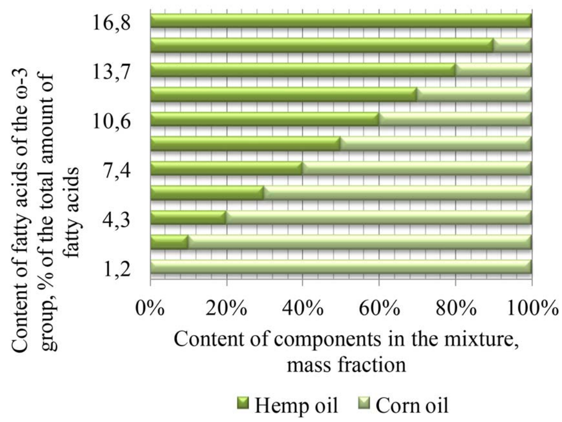

Fig. 2. Dependence of the content of ω-3 polyunsaturated fatty acids of the oil composition on the content of hemp and corn oils

Based on the obtained results of the experiments, a rational content of hemp and corn oils in the oil composition with satisfactory stability to oxidative deterioration and a physiologically significant content of polyunsaturated fatty acids of the ω-3 group is proposed, namely:

– content of hemp oil in the composition – 60±3 %;

– content of corn oil in the composition – 40±2 %.

With this content, the consumer properties of the oil composition are:

– the induction period of accelerated oxidation – 4.0 hours, i.e. 70 % more than that of hemp oil;

– the content of polyunsaturated fatty acids of the ω-3 group – 10.6 % of the total amount of fatty acids.

It is worth noting that an increase in the content of corn oil by more than 40±2 % leads to a decrease in the content of polyunsaturated fatty acids of the ω-3 group in the oil composition. This, in turn, reduces the nutritional value of the mixture, which is inappropriate from a physiological point of view, since the ω-3:ω-6 ratio will be lower than 1:5, which characterizes the oil composition as a healthy food product [9].

When the content of corn oil is reduced below 40±2 %, in turn, the stability to oxidative deterioration of the oil composition deteriorates, which negatively affects the consumer characteristics of the finished product.

5. 3. Study of the combined effect of essential oils on the period of induction of accelerated oxidation of the oil composition

The study of the period of accelerated oxidation of the proposed oil composition, stabilized by a complex of essential oils, was conducted. In the experiments, coriander, basil and thyme essential oils were chosen as antioxidants and at the same time flavoring agents. The composition of the samples of the selected essential oils according to the main components that were identified is given in Table 4.

In order to determine the rational ratio of the components of the complex of essential oils in the developed oil composition, the dependence of the period of induction of accelerated oxidation of the flavored oil composition (P (c_c, c_b, c_t)) on the ratio of essential components was investigated. Using equation (1), the approximate dependence of the period of induction of accelerated oxidation of the flavored oil composition on the ratio of essential oils is presented:

– coriander (c_c, mass fraction);
– basil (c_b, mass fraction);
– thyme (c_t, mass fraction).

$$P(c_c, c_b, c_t) = 9.28 \cdot c_c + 5.7086 \cdot c_b + 14.3086 \cdot c_t + 11.0571 \cdot c_c \cdot c_b + 10.1571 \cdot c_c \cdot c_t + 15.0429 \cdot c_b \cdot c_t. \quad (1)$$

Table 4

Composition of essential oils for stabilizing the oil composition

Name of essential components	Test samples, %		
	Coriander essential oil, c_c	Basil essential oil, c_b	Thyme essential oil, c_t
Linalaol	64.3±3.2	56.1±2.8	–
n-cymol	–	–	28.1±1.4
Methylchavicol	–	27.4±1.3	–
Carvacrol	–	–	16.8±0.8
γ-terpinene	–	–	13.8±0.6
Borneol	–	–	13.1±0.6
α-pinene	9.4±0.4	–	1.50±0.07
α-terpineol	–	–	7.3±0.3
Paracymenes	8.8±0.4	–	–
1,8-cineole	–	4.3±0.2	5.8±0.2
Limonene	3.9±0.1	–	1.10±0.05
Sabinene	2.2±0.1	–	1.4±0.07
Camphor	3.7±0.1	–	–
Terpineol-4	–	–	3.7±0.1
α-terpinene	–	–	2.3±0.1
Geranyl acetate	2.10.1±	–	–
Camphene	1.50±0.07	–	2.2±0.1
Thymol	–	–	1.20±0.05
Eugenol	–	1.20±0.05	–
β-myrcene	–	1.10±0.05	–

The surface of the obtained dependence of the period of induction of accelerated oxidation of the flavored oil composition on the ratio of essential oils is shown in Fig. 3.

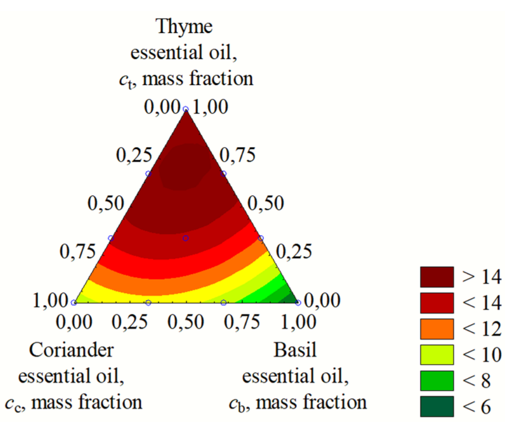

Fig. 3. Dependence of the period of induction of accelerated oxidation of the flavored oil composition on the ratio of essential oils

Thus, the ratio of essential oils in the complex is defined, with the addition of which the period of induction of accelerated oxidation of the flavored oil composition is 15.0±0.2 hours (calculated value – 15.1 hours):

– thyme essential oil 0.750±0.040 mass fraction;
– coriander essential oil 0.125±0.006 mass fraction;
– basil essential oil 0.125±0.006 mass fraction.

The flavored oil composition based on hemp oil of reasonable composition has a pleasant, warm, spicy-herbal aroma with a touch of greens.

6. Discussion of the results of the development of a flavored oil composition based on hemp oil

The consumer properties of refined hemp and corn oil were studied, namely:

– content of moisture and volatile substances (Table 1);
– analytical values that directly or indirectly show the intensity of lipid oxidation processes (Table 1);
– induction period of accelerated oxidation (Table 1);
– antioxidant composition (Table 2);
– fatty acid composition (Table 3).

It is proved that the samples of the selected oils meet the requirements of the regulatory documentation (CAS 89958-21-4; CAS 8001-30-7) according to the studied indicators. Also, the low oxidation stability of hemp oil (Table 1) compared to corn oil (Table 1) due to the lower content of tocopherols (Table 2) and the higher content of α-linoleic fatty acid (Table 3) is determined. The induction period of accelerated oxidation (Table 1) shows the different stability to oxidation of the studied oils. Accordingly, it can be predicted that the oxidation stability of corn oil will exceed that of hemp oil by almost 2 times (5.5 hours vs. 2.8 hours, respectively). The obtained result of the study indicates the feasibility of stabilization of refined hemp oil against oxidative destruction by developing an oil composition with refined corn oil and is explained by the effect of the antioxidant and triacylglycerol composition of corn oil on the inhibition of oxidative processes occurring in the lipids of hemp oil.

The combined effect of the content of hemp and corn oils in model samples of the oil composition on its period of induction of accelerated oxidation was studied (Fig. 1). In parallel, the content of polyunsaturated fatty acids of the ω-3 group in model samples of the oil composition was calculated (Fig. 2). The rational content of hemp and corn oils in the composition (6:4, respectively), with the ratio of fatty acids ω-3:ω-6 is about 1:5, which is acceptable for fat products for health purposes [9]. At the same time, the induction period of accelerated oxidation of the developed oil composition exceeds that of the original refined hemp oil (2.8 h) and is 4.0 h. The obtained result is explained by the decrease in the content in the oil composition and stabilization of the lipid components of hemp oil, in particular, α-linolenic acid, which are labile to oxidative damage, by the lipid components of corn oil (a complex of tocopherols, triacylglycerols of a lower degree of unsaturation).

In order to increase the oxidative stability of the developed oil composition, it is proposed to use a complex of essential oils (coriander, basil, and thyme), which are mutually compatible from an organoleptic point of view [22]. The composition of essential oils was studied (Table 4), it was found that the main essential components of the essential oil complex are as follows:

– linalool (64.3±3.2 % in coriander essential oil);
– *n*-cymol (28.1±1.4 % in thyme essential oil);
– methylchavicol (27.4±1.3 % in basil essential oil);
– carvacrol (16.8±0.8 % in thyme essential oil);

– γ-terpinene (13.8±0.6 % in thyme essential oil);

– borneol (13.1±0.6 % in thyme essential oil);

– α-pinene (9.4±0.4 % in coriander essential oil, 1.50±0.07 % in coriander essential oil), etc.

The combined effect of these essential oils on the period of induction of accelerated oxidation of blended oil of reasonable composition was studied (dependency (1), Fig. 3). A range of ratios of essential oils in the complex is proposed, with the addition of which the period of induction of accelerated oxidation of the flavored oil composition increases by 3.75 times compared to that of the oil composition without the addition of a complex of essential oils. Considering the results of the study (dependency (1), Fig. 3), this effect can be explained by the non-additive inhibitory effect of the components of the complex of essential oils studied on the oxidative deterioration, where the leading role probably belongs to (Table 4):

– *n*-cymol, carvacrol, γ-terpinene and borneol of thyme;

– linalool of coriander and basil;

– methylchavicol of basil.

The development differs from the results of the study [19], which investigated the antioxidant properties of aqueous extracts and essential oils of peppermint (*Mentha piperita*) and spearmint (*Mentha spicata*). Their rational concentrations in model fat systems for stabilization against oxidative damage without taking into account the combined effect were determined. Also, the development differs from the work [21], which investigated the influence of supercritical extracts of mint (*Mentha piperita*) and clove (*Syzygium aromaticum*) on the oxidative stability of model oil systems without varying the ratios of these extracts. In contrast to these research results, the developed flavored oil composition has a high content of α-linolenic fatty acid (Fig. 2), and is also stabilized against oxidative destruction by means of a complex of natural substances (Fig. 1, Table 1). The described technological and physiological properties are competitive advantages in the market of blended oils. This is due to the combination of different types of oils (labile to oxidation hemp and stable – corn), as well as a complex of natural antioxidants – essential oils (coriander, basil and thyme).

The regularities (Fig. 1, 2) establish a relationship between the induction period of accelerated oxidation (and, respectively, the shelf life) of the oil composition of hemp and corn oils and the content of α-linolenic fatty acid, which is the main physiologically active component of hemp oil. The data obtained can contribute to the wider use of hemp oil as an unconventional oil raw material by producers of the oil and fat industry.

Dependence (1) and its graphic representation (Fig. 3) allow us to have an idea of the effectiveness of the complex use of essential oils (thyme, coriander, bergamot) as multifunctional food additives – antioxidants and flavorings. The selected essential oils are not only harmoniously combined from an organoleptic point of view, but also have a certain inhibitory non-additive effect on the process of oxidative destruction of triacylglycerol oils. The data obtained can be applied when solving the issue of increasing the shelf life and expanding the organoleptic characteristics of a wide range of oil or fat raw materials.

The limitation of using the obtained research results is that the flavored oil composition based on hemp oil should be used only in the form of salad oil. The use of this product as a raw material for the production of oil-containing products (for example, mayonnaise or sauces) is not possible due to the presence of a certain content of aromatic substances in its composition. An option to overcome this limitation is to use the oil composition in the technology of oil-containing products with the adjustment of the content of the proposed complex of essential oils depending on the formulation of the corresponding products.

The disadvantage of the study is the lack of results of studies of the shelf life of the developed oil composition and flavored oil composition. It is known that the shelf life of oils is directly proportional to their periodic induction of accelerated oxidation. Thus, it is possible to calculate the shelf life of the developed products in view of the known shelf life of the raw materials (hemp and corn oils).

Promising areas of work are:

– study of the shelf life of the developed oil compositions (original and flavored) based on hemp oil under the recommended storage conditions;

– expanding the range of flavored oil compositions using other unconventional oils with high physiological value.

7. Conclusions

1. It was found that the samples of the selected oils (hemp and corn) according to the studied physico-chemical indicators and fatty acid composition meet the requirements of regulatory documentation (CAS 89958-21-4; CAS 8001-30-7, respectively). The induction period of accelerated oxidation at 80 °C for hemp oil was 2.8±0.1 h, and for corn oil – 5.5±0.2 h. The sum of tocopherol isomers in hemp oil is 688±27.5 mg/l, for corn oil – 6509±260.36 mg/l.

2. A rational ratio of hemp and corn oils in the oil composition of 6:4, respectively, is proposed. The consumer properties of this mixture are: the induction period of accelerated oxidation – 4.0 hours, the content of α-linolenic fatty acid – 10.6 % of the total amount of fatty acids.

3. It was found that the composition of essential oils (coriander, basil, thyme) selected for stabilization against oxidation includes, first of all, linalool, n-cymol, methylchavicol, carvacrol, γ-terpinene, borneol, α-pinene, etc. These substances have antioxidant properties, thus the combined use of these essential oils prolongs the period of induction of accelerated oxidation of the justified oil composition. The ratio of such essential oils in the complex is substantiated, with the addition of which the period of induction of accelerated oxidation of the flavored oil composition exceeds that of the initial one by 3.75 times: accordingly, essential oils of thyme, coriander, basil – 75:12.5:12.5.

Conflict of interest

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

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Data availability

The manuscript has no associated data.

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