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RESEARCH OF THE EFFECTS OF TECHNOLOGICAL FACTORS ON THE QUALITY INDICES OF HIGH OLEIC SUNFLOWER OIL

Досліджено показники якості олії соняшникової високоолеїнового типу (ОСВТ) та визначено їх зміни під впливом технологічних чинників (діапазону температур, тривалості термічного впливу, pH середовища). Визначено раціональні параметри технологічної обробки ОСВТ та розроблено рекомендації з її використання в технології продукції із заварного тіста.

Ключові слова: *олія соняшникова високоолеїнового типу, жирнокислотний склад, термічний вплив, заварне тісто.*

1. Introduction

As a result of increasing competition in consumer markets, an important task for the food industry and restaurant enterprises is the intensification of existing technological processes, the rational use of raw materials, and the increase in the range of products. This determines certain requirements for the ingredients and technologies of food products. The above concerns the production of custard products. In the production of custard products, the dough formation process is of significant importance. Along with the known influence of flour on the realization of the technological process of custard production, the technological properties of the fat component are important. Use in its composition as a fat component of butter, cream, margarine, spreads, hydrogenic oils of constantly growing cost, unsatisfactory fatty acid composition, short shelf life of products on their basis became a limiting factor, does not satisfy the needs of producers.

It has been analytically established that in the custard dough formation process, it is necessary to take into account the technological properties of the fat component. But system studies aimed at studying it as a prescription component of custard dough taking into account physical and physicochemical properties, fatty acid composition for the dough formation process and application properties of finished products are absent.

Innovative approaches in the production of fats provide the production of vegetable oils with the optimal fatty acid composition [1]. By induction of mutations with useful biochemical effects, a sunflower hybrid with high oleic acid glycerin content is derived from which production of high oleic sunflower oil (HOSO) is established. Oleic, monounsaturated fatty acids – heads the group of fatty acids of the ω-9 family, which have a positive effect on the cholesterol metabolism, prevent the incidence of people with heart disease and positively influence the composition of blood serum lipoproteins. This allows it to be positioned as a functional power component. Foreseeable, HOSO is characterized by high resistance to oxidation processes, both during storage, and under the influence of heat treatment.

In view of the foregoing, the rationale for the HOSO use in custard production technology is an important scientific and practical task of sectoral importance, the solution of which will create a scientific basis for the technology of new products.

2. The object of research and its technological audit

The object of research according TU U 15.4-13304871-007:2006 is HOSO and refined deodorized sunflower oil (RDSO) as control over DSTU 4492:2005.

The distinguishing HOSO characteristic is the modified fatty acid composition, which has a high content of triglycerides of oleic acid more than 89 %.

Characteristics of the composition and physicochemical parameters of oils are given in Table 1.

Table 1

Characteristics of the composition and physical and chemical properties of oils

Physical and chemical indicators	Oil	
	HOSO	RDSO (control)
Density ρ, kg/m^3, at $t=20\pm2$ °C	915…920	915…918
Density η, Pa·s, за $t=20\pm2$ °C	0.0180±0.0009	0.0175±0.0009
Solidification temparature t, °C	0…–6	–16…–19
Refractive index, at $t=20\pm2$ °C	1.466…1.468	1.474…1.475
Iodine number, IN, % I_2	105±5	119±6
Acid number, AN, mg KOH/g	0.112±0.003	0.330±0.009
Peroxide number, PN, mmol ½ O/kg	0.83±0.02	2.00±0.06
Saponification number, SN, mg KOH	184…194	186…194
Thiobarbit number, TbN, mg MA/1000 g, at a wavelength λ=535±10 nm,	0.0100±0.0003	0.0200±0.0006
Extinction coefficient, $E\ \frac{1\ \%}{1\ \text{cm}}$	3.00±0.09	3.60±0.10
The content of saturated fatty acids, %	7.95±0.24	10.51±0.52
The content of monounsaturated fatty acids, %	89.5±2.7	25.58±1.28
The content of polyunsaturated fatty acids, %	2.30±0.07	63.91±3.19
The total content of tocopherols, mg %	52.5±2.6	61.1±3.0

From Table 1 it can be seen that HOSO has the following characteristics:

$\rho = 915...920$ g/cm^3; $\eta = 0.0180 \pm 0.0009$ Pa·s;

$t_{(solidification)} = 0...-6$ °C; refractive index 1.466...1.468;

TbN = 0.0100 ± 0.0003 mg MA/1000 g;

PN = 0.83 ± 0.02 mmol ½ O/kg, SN = 184...194 mg KOH;

AN = 0.112 ± 0.003 mg KOH/g, IN = 105 ± 5 % I_2;

$$E\frac{1\,\%}{1\,\text{cm}} = 3.00 \pm 0.09.$$

The fatty acid composition of the test HOSO is given in Table 2.

Table 2

Fatty acid composition of oils

Oil	Fatty acid content, %			
	Palmitic C16:0	Palmitoleic C16:1	Stearic C18:0	Oleic C18:1
RDSO	6.83±0.34	0.140±0.005	3.68±0.18	25.44±1.27
HOSO	3.93±0.11	0.180±0.005	2.82±0.08	89.3±2.7
Oil	Linoleic C18:2	Linolenic C18:3	Eicosenic C20:0	Behenic C22:0
RDSO	62.61±3.13	0.190±0.005	0.150±0.005	0.70±0.02
HOSO	2.00±0.06	0.30±0.009	0.50±0.01	0.70±0.02

The results of the study of the fatty acid composition of the experimental oil samples are established, represented by 10 fatty acids, including:

– palmitic (C16:0);
– palmitoleic (C16:1);
– stearic (C18:0);
– oleic (C18:1);
– linoleic (C18:2);
– linolenic (C18:3);
– arachine (C20:0);
– palmitolinoleic (C16:2);
– behenic (C22:0);
– other acids, the total content of which does not exceed 2 % and is not critical for the oil quality.

The identification parameters of oils for fatty acid composition differ very low content of linolenic, begenic and palmitoleic acids, the total number of which does not exceed 0.7 %. One of the most problematic places of HOSO is that natural oils faster than solid fats oxidize and products have a shorter shelf life.

3. The aim and objectives of research

The aim of research is development of recommendations for the HOSO use in food technology, in particular, custard products.

To achieve the aim it is necessary to solve the following tasks:

1. To investigate the influence of technological factors on the physicochemical and technological properties of HOSO.

2. To determine the rational parameters of HOSO technological processing.

4. Research of existing solutions of the problem

It has been analytically confirmed that the implementation of the custard production technology is determined by the technological characteristics of the fat component, influences the rheological, structural and mechanical properties of the finished product. So, it is advisable to investigate the behavior of the fat component in the technological process, taking into account the criteria: raw material; physiological; technological.

Today in the custard production technology as a fat component is used: butter, margarine, culinary fat, coconut and rapeseed oil, hydrogenized oils, shortenings [2–4].

The existing technologies of custard dough need to be improved. At times, one of the most important requirements for custard products is high taste characteristics, balance in biological value, proper quality for a long shelf life, a wide range of products [5]. In this direction, many studies have been carried out [2, 6], however, their systemicity is absent.

The authors of [7–9] studied the effect of the fatty acid composition, differing in the length of the carbon chain and the saturation degree, on the complexation of their proteins and starch flour polysaccharides in the model system of custard dough. It is determined that the unsaturated fatty acids interact more efficiently interacted with bonded protein, and the binding strength increases with the increase in the degree of non-acidity of acids, due to the reactivity of the double bonds [10–12]. The interaction of lipids with molecules of starch polysaccharides occurs by incorporating lipids in the helix of polysaccharide molecules. The formation parameters and the properties of starch-lipid complexes are rather widely represented in [2–4, 6]. The formation of complexes is determined not only by the structure of the lipid molecule, but by the degree of their polarization, but by the temperature of the medium and an increase in the pH and temperature, the ability of lipids to form complexes with starch polysaccharides increases, since the water bonds of the polysaccharides are weakened and the number of glucose residues from the dihydrocyanide of the hydroxyl groups increases. The process of a hydrothermal treatment also contributes to the formation of lipid-polysaccharide complexes. Amylose and amylopectin are involved in the formation of complexes. However, amylopectin is much less able to form such complexes than amylose [2–4].

The melting temperature and the aggregate state of fat significantly affect the degree of plasticisation of the custard. It has been established that during the preparation of the dough and its baking intensive binding of lipids occurs – more than 75 % of free lipids, including 90 % of glyco-and phospholipids and 66 % of triglycerides [6, 12, 13].

In the technological process of manufacturing custard products, fats not only affect the structural and mechanical properties of the dough, but also determine the duration of storage of finished products [6]. The fat content in the custard products is 13.5 %, and the shelf life of this product varies widely from $(12...72) \times 60^2$ s at $t = 0...6$ °C (production of restaurants) to 360 days for $t = -18$ °C (food products). So, to produce the custard products, it is necessary to use fats that are resistant to oxidation processes.

Nutritionists recommend that edible fat products meet the following requirements [12–14]:

– have a balanced fatty acid composition;
– contain unsaturated omega-3, omega-6 and omega-9 fatty acids;
– have a minimum content of cholesterol and trans-isomers of fatty acids.

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Deficiency of essential (polyunsaturated) fatty acids and high cost of fats used in the technology of custard products, encourage the producer to seek an alternative replacement for other raw materials. To ensure the recommended fatty acid composition in the human diet, a ratio of 1/3 vegetable oils and 2/3 fats of animal origin must be maintained. This ratio can vary depending on the group of consumers: for the elderly it should be 1:1.

The source of essential fatty acids in the production of flour confectionery products (FCP), including custard products, can be vegetable oils. In the world practice there is a certain experience in the FCP production with the addition of oils. The use of oil makes it possible to enrich the products with unsaturated fatty acids, especially indispensable, and also to reduce its cost by eliminating butter and margarine products and attracting raw materials of domestic origin.

Monitoring of existing recipes has shown that technologies are increasingly being used, where shortenings and other oil-in-water emulsions are used as fat components of the dough, which improve the dough structure and the quality of the finished product.

Based on the analysis of literature sources, it is established that the quality of the finished custard product is heavily influenced by the fatty recipe component and the parameters of the technological process. Theoretical bases and practical aspects of the development of scientists [6, 12–16] are not systemic in nature and do not allow to give scientifically grounded recommendations for complete or partial replacement of the fat component. In connection with the latter, there is a need to find an alternative oil change in the technology of the custard products.

5. Methods of research

The hydrolysis degree that occurred in the oils was indicated by the indicators of the acid number and the saponification number. Determination of the saponification number (SN) of oils was carried out in accordance with GOST 5478-64. Determination of the acid number (AN) of oils was carried out in accordance with GOST 5476-80. The essence of the method consists in dissolving a certain mass of oil in a mixture of solvents, followed by titration of the existing free fatty acids with an aqueous or alcoholic solution of potassium or sodium hydroxide. The acid value of the oil (X_1), mg KOH/g, was calculated from formula (1).

$$X_1 = \frac{5.611 \cdot K \cdot V}{m}, \quad (1)$$

where 5.611 – the coefficient equal to the calculated mass of KOH in 1 ml of 0.1 normal KOH solution; K – correction to the titer of 0.1 normal solution of potassium hydroxide; V – the volume of 0.1 normal potassium hydroxide consumed per titration, ml; m – the oil mass, g.

Determination of the peroxide number of oils was carried out according to DSTU ISO 3960-2001. The essence of the method consists in dissolving a certain mass of oil in a mixture of solvents, followed by titration of existing hydroperoxides with a solution of sodium thiosulfate with the subsequent processing of the results and determination of the peroxide number of oil (PN), mmol/kg, was determined by the formula (2).

$$X = \frac{(V - V_0) \cdot 1000 \cdot c}{m}, \quad (2)$$

where V – the volume of sodium thiosulfate solution in the main experiment, cm^3; V_0 – the volume of sodium thiosulfate solution in the control experiment, cm^3; c – the concentration of sodium thiosulfate solution, mol/dm^3; m – the mass of the test sample, g.

Determination of the density of the oil samples was carried out in accordance with DSTU 4633:2006.

The degree of custard dough non-invasiveness was determined from the value of the iodine number (IN), by titration with the hydrochloric acid solution of iodine chloride according to GOST 5475-69.

Determination of the content of secondary oxidation products was carried out by the magnitude of the thiobarbit number. Thiobarbit number (TbN) in mg of malondialdehyde per 1000 g of fat was calculated by the formula:

$$TbN = [\lg(100/T) \cdot K]/m, \quad (3)$$

where T – the coefficient of filtrate transmittance; $\lg(100/T)$ – the optical density of the filtrate; K – factor in the case of using light filters with excellent 2-thiobarbituric acid 21 wavelength, for different colorimeters is established experimentally; m – sample of the substance in g.

The result is expressed in mg of malondialdehyde per 1000 g of fat (mgMA/1000 g).

Determination of the dynamic viscosity of the oil samples (η) was carried out on the Heppler rheoviscosimeter (Germany), using the following formula:

$$\eta = P \cdot \tau \cdot \kappa, \quad (4)$$

where η – the dynamic viscosity, Pa·s; P – sample, g/cm^2; τ – time, s; k – the constant of a dimensional cylinder.

The specific absorption (extinction coefficient) $\left(E\,\frac{1\,\%}{1\,\text{cm}}\right)$ was determined from the wavelength λ = 232 nm (oil oxidation limit) and was calculated by the formula:

$$E\,\frac{1\,\%}{1\,\text{cm}} = L_{232} / C, \quad (5)$$

where L_{232} – the optical density of the oil solution at a wavelength λ = 232 nm; C – the percentage concentration of the oil solution, numerically equating m.

Specific refractive index (n) of oil samples was determined according to DSTU ISO 6320-2001.

To determine the amount of saturated and unsaturated fatty acids, a method was used to determine the fatty acid composition based on the conversion of triglycerides of fatty acids to methyl esters of fatty acids and gas chromatographic analysis of the latter [17].

Determination of the content and composition of tocopherols was carried out by the method of high-performance liquid chromatography on the chromatographic system Smartline by Knauer (Germany) using the EurospherII-5-SI 250×4 column.

6. Research results

6.1. Investigation of HOSO physicochemical parameters and their change during storage. To date, oil for use in

the technological process of manufacturing custard products, as a prescription component, is chosen with certain physico-chemical and technological properties [5, 9]. For the technology of preparation of culinary products, in particular the custard products, it is planned to use HOSO as an alternative replacement of butter.

Despite the fact that the object of research is HOSO, its technological and physico-chemical indices have been studied, a comparative characteristic has been made with oil similar to RDSO as a control.

It is known that of all the components of food fats are the most vulnerable to the action of various factors that cause changes in their properties and cause a change in the quality of the finished product. Despite the fact that the composition of the oils includes a group of unsaturated chemical compounds that make their reactions possible, studies have been made of the changes in the basic physicochemical parameters and the fatty acid composition of the oils:

– during storage (t=20±2 °C, τ=24 months);
– under the influence of temperatures (t=0...100 °C);
– under conditions of prolonged thermal impact (t= =180±2 °C, τ=(0...30)×60^2 s);
– under hydrothermal conditions.

To objectively evaluate the transformations occurring in oils during storage, physico-chemical indices are studied: AN, PN, IN, dynamic viscosity and refractive index.

Fig. 1, 2 show the dependencies of the above indices on the duration of storage of oils. The totality of the obtained data makes it possible to characterize the rate and degree of hydrolysis and oxidation processes. Analysis of the obtained data (Fig. 1) allows to state that the hydrolysis process of the oil samples is irreversible – AN of both samples gradually increases during the entire storage period. In the control sample (RDSO), the hydrolysis process is observed from the beginning of storage, the accumulation degree of hydrolysis products in it is higher than in HOSO, 3 times for 24 months of storage.

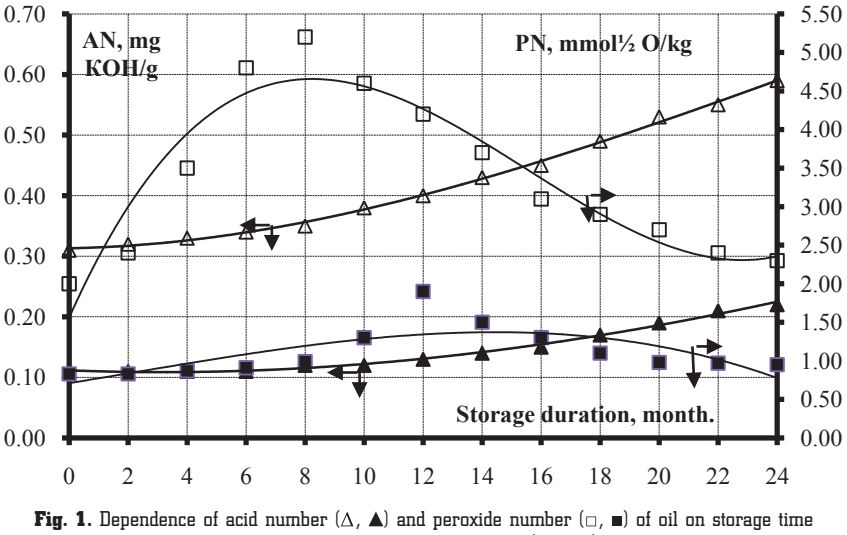

Fig. 1. Dependence of acid number (Δ, ▲) and peroxide number (□, ■) of oil on storage time for t=20±2 °C: refined deodorized sunflower oil (control) – light markers; high oleic sunflower oil – dark markers

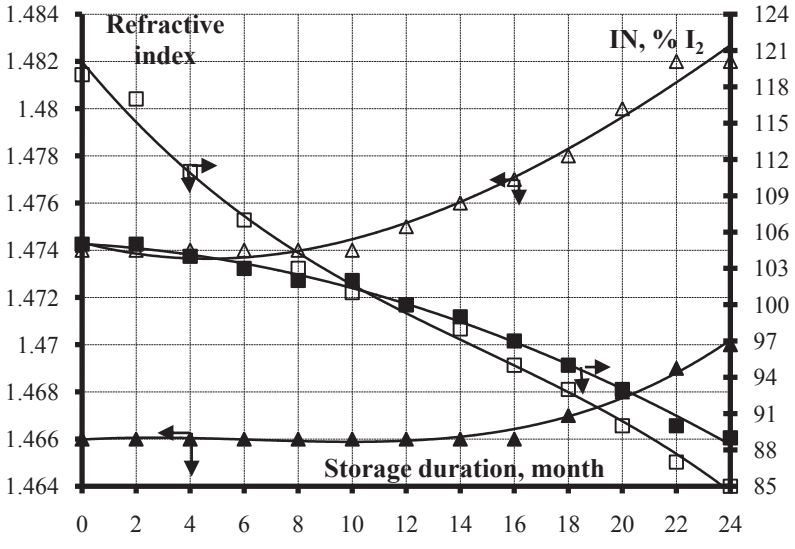

Fig. 2. Dependence of iodine number (□, ■) and refractive index (Δ, ▲) of oil on storage time for t=20±2 °C: refined deodorized sunflower oil (control) – light markers; high oleic sunflower oil – dark markers

From the literature sources [9–11] it is known that the processes of fat oxidation are based on their interaction with oxygen. Substrates of this reaction in general form are unsaturated fatty acids. The study of PN of the oil samples during storage indicates that the nature of the change in the PN is unstable. The results of the conducted studies of PN of the oil samples during storage indicate that in the RDSO (control) peak accumulation of hydroperoxides (primary oxidation products) is observed from 6 to 10 months of storage and reaches 5 mmol ½ O/kg, while in HOSO, an increase in PN is observed only from the 10th month and is 1.98 mmol ½ O/kg. The IN of both oil samples after a maximum is intensively reduced, which indicates the formation of volatile compounds.

It has been established that glycerides, which contain unsaturated fatty acids, confirm the data of iodine number and refractive index tests during the storage of oils (Fig. 2). The iodine number of both oil samples decreases during the entire storage period. It is revealed that the decrease in the non-invasiveness degree in the RDSO (control) occurs more rapidly than the HOSO.

Investigation of the oil viscosity during storage shows that the RDSO viscosity increases from the first months of storage and reaches a maximum of 0.027±0.001 Pa·s, which in 24 months is 1.3 times higher than that in HOSO – 0.020±0.001 Pa·s. Compared with the control, the dynamic viscosity curve of HOSO has a stable character during 16 months of storage. Since the oil viscosity depends on the content of saturated fatty acids, conjugated bonds and trans-isomers in them, the results suggest that the increase in the RDSO viscosity is associated with a change in the spatial structure of free fatty acids.

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Dynamics of TbN of oils indicates an increase in the content of secondary oxidation products from the 6th month of storage in RDSO (control) by 3 times and from the 12th month in HOSO by 2 times compared with the baseline.

The growth of the extinction coefficient indicates that during the entire storage period in both samples of the oils, the isolated systems of double bonds are isomerized into conjugated systems. Thus, the RDSO extinction coefficient has increased from the initial level by 5 times and HOSO – 3 times.

The dynamics of fatty acid composition of oils indicates that during RDSO and HOSO storage the content of saturated fatty acids increases from 7.9 % to 8.7 % and from 11.4 % to 12.5 %, respectively. And the number of polyunsaturated fatty acids decreases from 2.3 % to 1.9 % and from 62.8 % to 56.5 %, respectively, which correlates with the results of studies of physicochemical parameters. The dynamics of the content of monounsaturated fatty acids is different: in HOSO, their content is reduced to 89.5...86.2 %, and in the RDSO (control) increases to 25.6...28.1 % within 24 months.

The content of tocopherols in oils during storage (Table 3) decreases in both samples, namely, by 1.5 times in RDSO (control) and by 1.1 times in HOSO, which indicates a decrease in their antioxidant potential during storage.

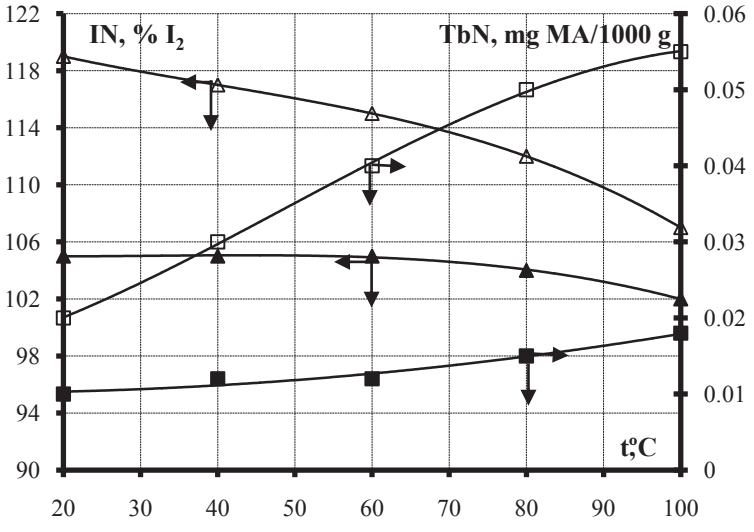

Fig. 3. Dependence of iodine number (Δ, ▲) and thiobarbit value (□, ■) of oil on temperature: refined deodorized sunflower oil (control) – light markers; high oleic sunflower oil – dark markers

It has been established that the TbN index correlates with the AN and IN values of oils, TbN of HOSO does not change in the temperature range 20...60 °C, while for the RDSO (control) the TbN growth is within 0.02...0.055 mg MA/1000 g.

Experimental studies indicate a decrease in the total content of tocopherols in the oil samples with an increase in temperature, namely 7.7 % in RDSO and 5.1 % in HOSO, which confirms a more intensive RDSO oxidation compared to HOSO.

Table 3

The content of tocopherols in oils at storage $t = 20 \pm 2$ °C, mg %

Oil	Storage duration, months							
	0	3	6	9	12	18	21	24
RDSO (control)	61.1±3.0	55.3±2.8	52.8±2.6	48.4±2.4	46.2±2.3	44.2±2.2	42.6±2.1	40.5±2.0
HOSO	52.5±2.6	51.8±2.6	50.4±2.5	49.5±2.5	48.8±2.4	48.0±2.4	47.3±2.4	46.6±2.3

To justify the HOSO use as a prescription component of custard products and the medium for deep frying, it is considered expedient to investigate the HOSO properties during long-term heat treatment ($t = 180 \pm 2$ °C, $\tau = 30 \times 60^2$ s). It has been established that AN of both oil samples during heat treatment increases (Fig. 4).

An important stage of the study is the determination of rational parameters for the HOSO thermal processing. It has been established that the refractive index in HOSO does not change under the influence of temperature and is 1.466, while in the RDSO (control) it increases in the range 1.474...1.476. This indicates the accumulation in the HOSO (control) of substances with new functional groups.

Studies of the PN and AN dynamics in the samples of both oils with increasing temperature have established that parallel processes of hydrolysis and oxidation with different intensities occur. PN and AN for RDSO (control) grow in conditions of temperature increase from 20 to 100 °C and exceed these data in HOSO by 3.0 and 2.5 times, respectively.

The iodine number of oils (Fig. 3) for HOSO is 105 % I_2, and 119 % I_2 for RDSO (control), and with decreasing temperature, the iodine number decreases to 102 % I_2 and 106 % I_2, respectively. Decrease in IN indicates not only a decrease in the degree of non-violence, but also about isomerization. To determine the content of aldehydes in oil samples during heat treatment, the dynamics of TbN are studied (Fig. 3).

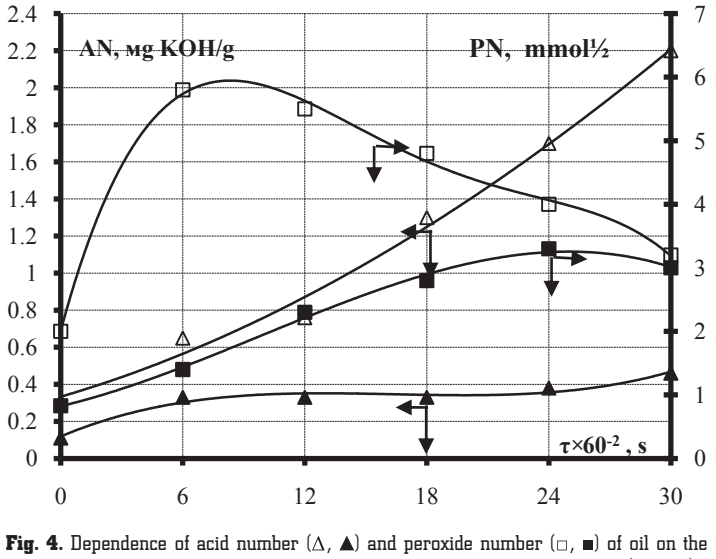

Fig. 4. Dependence of acid number (Δ, ▲) and peroxide number (□, ■) of oil on the heat treatment duration for $t = 180 \pm 2$ °C: refined deodorized sunflower oil (control) – light markers; high oleic sunflower oil – dark markers

After a 30-hour period, AN for HOSO is increased from the initial value 4.2 times and remains sufficiently low – 0.46 mg KOH/h, AN for RDSO (control) increases by 7.1 times – 2.2 mg KOH/h. The oxidation rate in HOSO below the RDSO (control) by 2 times at the beginning of heat treatment and by 1.23 times with the maximum duration of heat treatment.

Polymerization and isomerization of triacylglycerols of unsaturated fatty acids in oil samples during prolonged heat treatment ($t = 180 \pm 2$ °C) is confirmed by studies of viscosity and extinction coefficient (Fig. 5).

In the interval of heat treatment duration 6...30 hours, a linear relationship between the extinction coefficient and the heat treatment duration is observed. The extinction cotfficient in the RDSO (control) and HOSO grows to the limit of maximum permissible values after 6 hours in RDSO and 18 hours in HOSO ($E\frac{1\,\%}{1\,\text{cm}} = 15$ which corresponds to the accumulation of 1 % of oxidized fatty acids). This confirms the thermal resistance of HOSO that is 3 times greater.

It is proved that simultaneously with an increase in the extinction coefficient, TbN for oils (Fig. 5) also increases that confirm the formation of secondary oxidation products. TbN index in HOSO is 0.04 mg MA/1000 g, which is 2.25 times less than TbN for RDSO (control). Reduction in the degree of unsaturation of the oils is illustrated by the results of the IN study (Fig. 6). The rapid disintegration of triacylglycerols is observed for 6...18 hours, as a result of which the IN of RDSO (control) decreases from 119 % I_2 to 95 % I_2, that is, by 1.2 times of the initial value, and in HOSO – by 1.1 times.

During heat treatment, essential changes occur in the fatty acid composition of oils, the nature of which depends on the type of oil and the heat treatment duration. The dynamics of the content of saturated fatty acids for thermal exposure is shown in Tables 4, 5.

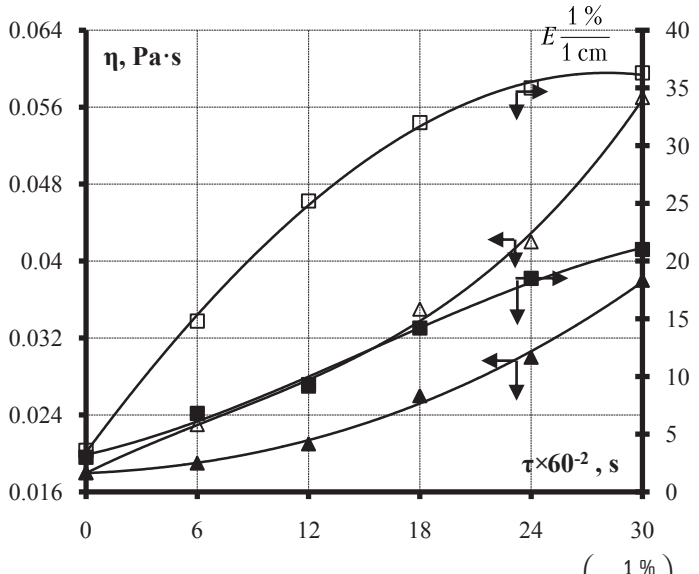

Fig. 5. Dependence of viscosity (Δ, ▲) and oil extinction coefficient $\left(E\frac{1\,\%}{1\,\text{cm}}\right)$, (□, ■) on the heat treatment duration for $t = 180 \pm 2$ °C: refined deodorized sunflower oil (control) – light markers; high oleic sunflower oil – dark markers

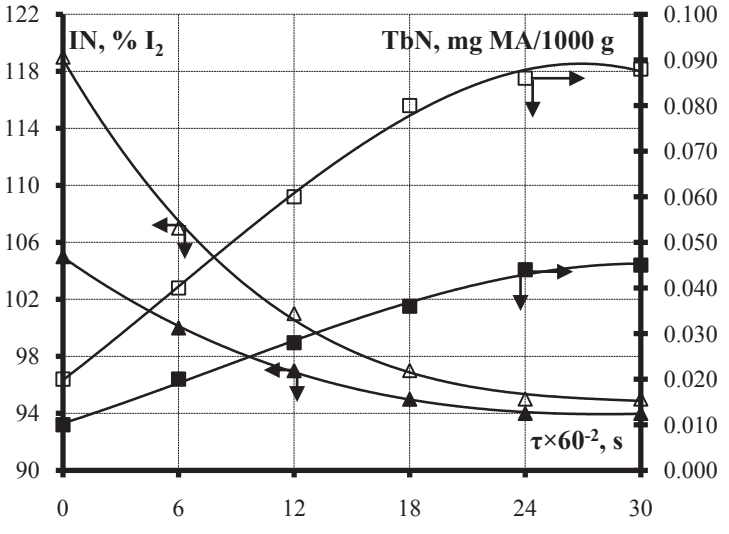

Fig. 6. Dependence of iodine number (Δ, ▲) and TbN (□, ■) of oil on the heat treatment duration for $t = 180 \pm 2$ °C: refined deodorized sunflower oil (control) – light markers; high oleic sunflower oil – dark markers

Table 4

Dependence of palmitic acid content (% of the total) in the test oil samples on the heat treatment duration

Oil	Heat treatment duration, ×60⁻² s					
	0	6	12	18	24	30
RDSO (control)	6.8	7.5	8.1	8.5	9.3	10.2
HOSO	3.9	4.0	4.1	4.3	4.5	4.8
$MPD^*_{0.05}$	0.1					

Note: * – The most probable difference, the effects are reliable at 5 percent level.

The content of saturated fatty acids during prolonged heat treatment of both oil samples increases. An increase in the content of palmitic (from 3.9 % to 4.8 %) and stearic (from 2.8 % to 3.6 %) acids is observed in HOSO, in the RDSO (control) – (from 6.8 % to 10.2 % and from 3.7 % to 5.6 % respectively). In the RDSO (control), the increase in the content of palmitic and stearic acids during heating is more intense than in HOSO.

Table 5

Dependence of stearic acid content (% of the total) in the test oil samples on the heat treatment duration

Oil	Heat treatment duration, ×60⁻² s					
	0	6	12	18	24	30
RDSO (control)	3.7	4.1	4.3	4.6	5.1	5.6
HOSO	2.8	3.0	2.9	3.2	3.4	3.6
$MPD^*_{0.05}$	0.1					

It is established (Table 6) that HOSO is characterized by a high content of oleate (89.3 %), which is 3.5 times higher than in RDSO (control). The nature of changes in the content of oleate during the long-term heat treatment is specific for each of the test oil samples. The content of oleic acid in HOSO during long-term heat treatment

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decreases from 89.3 % to 83.6 %, due to the oxidation of oleic acid, and in the RDSO (control) – intensively increases from 25.5 % to 33.4 %, which can be explained two parallel processes – the oxidation and hydrogenation of polyunsaturated fatty acids (PUFA).

Table 6

The content of oleic acid (% of the total) in the test oil samples by thermal effect

Oil	Heat treatment duration, $\times 60^{-2}$ s					
	0	6	12	18	24	30
RDSO (control)	25.5	27.3	28.7	29.7	31.5	33.4
HOSO	89.3	86.1	85.5	85.0	84.8	83.6
$MPD^*_{0.05}$	0.3					

The content of linoleic acid in the samples of oil in the course of long-term thermal effects decreased (Table 7). In HOSO, the content of linoleic acid in the process of heating is decreased from 2.00 to 1.61 %, which may indicate the specificity of the structural arrangement of the linoleic acid in the triacylglitzer molecule, while the quantitative content of linoleic acid in RDSO (control) decreases from 62.6 to 48.4 %.

Table 7

The content of linoleic acid (% of the total) in the test oil samples by thermal impact

Oil	Heat treatment duration, $\times 60^{-2}$ s					
	0	6	12	18	24	30
RDSO (control)	62.6	59.5	57.2	55.0	51.9	48.4
HOSO	2.00	1.70	1.68	1.65	1.63	1.61
$MPD^*_{0.05}$	0.3					

The generalization of the results of the studies confirms that HOSO is characterized by greater stability of the fatty acid composition with prolonged heat treatment in comparison with the RDSO (control).

The total content of tocopherols in RDSO (control) is 61.1 mg %, and in HOSO – 52.5 mg %. The quantitatively predominant form of tocopherols in the samples analyzed is α-tocopherol. Its share in the tocopherol complex is 93.9 mg % and 94.6 mg %, whereas the proportions of β-, γ- and δ-tocopherols are 3.8 mg % and 4.5 mg %; 1.4 mg % and 1.5 mg %; 0.2 mg % and 0.3 mg %, respectively (Table 8).

Table 8

The content and composition of tocopherols in the test oil samples

Oil	Total content of tocopherols in oils, mg %	The content of isoforms of tocopherols, % to the sum			
		α-tocopherol	β-tocopherol	γ-tocopherol	δ-tocopherol
RDSO (control)	61.1	93.9	4.5	1.4	0.3
HOSO	52.5	94.6	3.8	1.5	0.2
$MPD^*_{0.05}$	4.5	1.7	1.1	0.8	0.1

The test oil samples differ significantly in the dynamics of the content of α-tocopherol during prolonged heat treatment (Table 9). In RDSO (control) for 6 hours of heat treatment, the content of α-tocopherol is reduced by 46.7 %, 12 hours by 75.8 %, 18 hours by 90.4 %, 24 hours by 94.1 %, 30 hours – by 99.0 %. For HOSO – by 41.1 %, 68.2 %, 84.6 %, 91.2 % and 97.0 %, respectively. This indicates a greater HOSO stability for oxidation processes in comparison with RDSO (control).

Table 9

Content of α-tocopherol in test oil samples for thermal effects, mg %

Oil	Heat treatment duration, $\times 60^{-2}$ s					
	0	6	12	18	24	30
RDSO (control)	57.3	30.6	13.9	5.5	3.4	0.6
HOSO	49.7	29.3	15.8	7.7	4.4	1.5
$MPD^*_{0.05}$	1.6					

In order to develop recommendations for the further use of HOSO in the technology of custard products, the dynamics of the properties of oils in the technological system under the influence of hydrothermal processing was investigated.

It has been established that during the flow of hydrothermal processes in the «HOSO-water» model systems based on HOSO with a different reaction of pH 4.5, 6.0, 8.0, the chemical transformations of triacylglycerols – hydrolysis and oxidation – occur at different intensities.

HOSO-based model systems show great thermal stability and resistance to peroxidation as compared to RDSO (control)-based samples. The maximum values of SN and PN do not exceed 0.74 mg KOH/g and 3.45 mmol ½ O/kg, respectively, in conditions of increasing the proportion of water in the system (1.0:0.5, 1.0:2.5, 1.0:3.0), an increase in temperature to 100 °C, an increase in the duration of thermal exposure to 40×60 s.

The rational conditions of the hydrothermal process for the «HOSO-water» model systems based on HOSO have been determined, according to which the temperature is 95...100 °C, the duration is 5×60 s, the hydromodule «HOSO-water» is 1.0:2.5. The conducted researches became a basis for development of scientifically based technology with the use of HOSO in the production of custard products.

6.2. Development of recommendations on the HOSO use in the technology of custard products and as a medium for frying. It has been experimentally established that HOSO is characterized by changed FAC that has a high content of oleic acid and differs from RDSO (control) with higher resistance to oxidation processes. Due to the technological HOSO properties, it is expedient to use it in technologies that require resistance to oxidation processes, both during storage and under the influence of technological factors.

Generalization of analytical and experimental studies of HOSO technological indicators allows to determine the rational parameters of technological processing (Table 10) and develop recommendations for its use.

In view of the foregoing, it is recommended to use HOSO as:

– a prescription component;
– medium for frying, in particular deep-frying.

Table 10

Rational parameters of HOSO technological processing

Parameter	Units	Boundary values
Oil as a medium for frying		
Temperature	°C	160…180
Ratio of oil: s/p	–	4:1
Duration of continuous use	$\times 60^2$ s	0…18
Duration of HOSO storage	month	24
Oil as a recipe component of a custard products		
Temperature of hydrothermal treatment	°C	95…100
Duration of hydrothermal treatment	×60 s	3…5
The ratio of oil:water	–	1:2,5
pH of the medium	–	6
Duration of storage of finished products, at t=0...6 °C and relative air humidity of 70...75 %	hours	0…12

Let's assume that the observance of rational parameters of HOSO technological processing will allow satisfying the principles of developing new products:

– use of domestic raw materials;

– maximum realization of HOSO functional-technological properties with obtaining high-quality products;

– production of products using OSVT, in the technology of which industrial approaches are implemented;

– reduction of energy consumption and labor intensity of the process;

– introduction of resource-saving technologies using the newest principles of food production.

7. SWOT analysis of research results

Strengths. HOSO use in the production of culinary products will allow to:

– increase the nutritional and biological value of products due to the content of monounsaturated fatty acids of the ω-9 family in the oil;

– exclude consumption of trans-isomers;

– improve the organoleptic characteristics and consumer properties of food;

– solve the problems of rapid oxidation and a significant deterioration in the organoleptic characteristics of the oil in the manufacture of culinary products requires a long heat treatment (flour confectionery and culinary products, deep fryers, frying, etc.), which will provide an economic effect.

Weaknesses. HOSO disadvantage is the melting point and the aggregate state of fat, which limits the possibility of its use in technologies that require a solid form of fat. Since it is known that oils, in comparison with solid fats, are not well supported by dough and finished products, the oil is extruded when storing the products, leaving greasy stains on the wrappers.

Opportunities. One of the possible ways to solve this problem is the HOSO introduction in the dough composition in the form of emulsions. Recently there has been an active search for effective emulsifiers and stabilizers of emulsions. Another embodiment of this disadvantage is the transformation of the sunflower viscolein oil into a solid state by adding beeswax or incorporating complex distilled monoglycerides with lecithin into the dough formulation.

Threats. The risks of HOSO use consist in:

– decrease in the yield of sunflower gibid from HOSO is obtained;

– non-observance of recommendations for HOSO storage and use.

8. Conclusions

1. The influence of technological factors on the physicochemical and technological properties of HOSO is investigated. It is proved that during HOSO storage is more resistant to oxidation processes in comparison with RDSO, since glycerides of polyunsaturated fatty acids oxidize faster than monounsaturated, confirming experimental data of physicochemical parameters, fatty acid composition and dynamics of tocopherol content. HOSO stability for oxidation processes under conditions of prolonged thermal action in comparison with RDSO (control) by functional numbers (acid, peroxide, iodine, thiobarbituric) is studied. It is found that the oxidation rate in HOSO is lower than in RDSO (control) by 2 times at the beginning of the heat treatment and by 1.23 times with the maximum duration of heat treatment. The extinction coefficient rises to the limit of the maximum permissible values ($E\frac{1\,\%}{1\,\text{cm}}=15$ that corresponds to the accumulation of 1 % oxidized fatty acids) from 6 hours in RDSO and 18 hours in HOSO, which confirms the HOSO thermal stability that is 3 times greater. Essential changes in the fatty acid composition and the complex of tocopherols of oils under heat treatment conditions, the nature of which depends on the type of oil and the duration of heat treatment, are also shown, which also indicates a greater stability of HOSO for oxidation processes in comparison with RDSO (control) and allows to recommend HOSO as a medium for frying and prescription component of fat-containing products. Changes in the main technical and technological indices of HOSO during the course of hydrothermal processes are studied. The regularities of the influence of the hydrothermal treatment method on the technological indexes of HOSO are established, proving the expediency of using HOSO in technologies with hydrothermal constituents, in particular, in the technology of custard products.

2. Recommendations on the HOSO use in the technology of custard products and as a medium for frying are developed. Rational conditions of the brewing process are t=95...100 °C, $\tau=(3...5)\times 60$ s, hydromodule «HOSO-water» – 1:2.5. Recommended parameters for the HOSO use as a medium for frying, in particular deep-fried: t=160...180 °C, duration of continuous use $\tau=(0...18)\times 60^2$ s, ratio «HOSO – semifinished product» is 4:1, HOSO storage time is 24 months.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ТЕХНОЛОГИЧЕСКИХ ФАКТОРОВ НА ПОКАЗАТЕЛИ КАЧЕСТВА МАСЛА ПОДСОЛНЕЧНОГО ВЫСОКООЛЕИНОВОГО ТИПА

Исследованы показатели качества масла подсолнечного высокоолеинового типа (МПВТ) и установлено их изменения под влиянием технологических факторов (температуры, продолжительности термического воздействия, pH среды). Определены рациональные параметры технологической обработки МПВТ и разработаны рекомендации по использованию его в технологии продукции из заварного теста.

Ключевые слова: масло подсолнечное высокоолеинового типа, жирнокислотный состав, термическое воздействие, заварное тесто.

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