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New recipiles for shortening fats and studying their basic technological characteristics

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Abstract. This study examined the qualitative indicators and physicochemical characteristics of cottonseed, soybean, and linseed oils, as well as their processed products, with the aim of developing new types of shortening fats. The research established that to achieve the required quality and physicochemical characteristics in shortenings from vegetable oils, the following parameters must be observed: phospholipid content (0.97-2.35%), tocopherol content (0.57-1.69 mg/kg), acidity (0.17-0.35 mg•KOH 1 g), and peroxide number (3.1-4.6 mol/kg). Based on these findings, new formulations for shortening fats were proposed using hydrogenated cottonseed (10-90%) and soybean (40-60%) oils, as well as linseed oil (5-10%). The effective and rational use of local fat sources resulted in improved quality and a minimum content of trans acids, ensuring the food safety of the shortenings. The study also established the role and significance of the quantitative content (15–95%) of hydrogenated fatty acids (Tm=30.7-31.4 °C, Tw=180-200 g/cm) and trans-isomerized fatty acids (3.1-4.7%) in the formation of quality indicators and physical and chemical characteristics of the developed shortenings.

1 Introduction

Vegetable oils and solid fats are widely used in public catering, for the preparation of margarine products, shortening fats for special purposes, bakery and confectionery products [1,2,3]. Currently used for these purposes as a source of raw materials, cottonseed oil and its processed products are distinguished by their unique physical and chemical characteristics, chemical composition, quality indicators and biological value, which determine the food safety of the resulting products [4,5,6].

Scientific research is being conducted to expand the raw material base and improve the quality of margarine products and shortening fats; modernization of their production technology using new types of raw materials.

Existing methods for producing shortening fats are characterized by certain technological advantages and disadvantages. Recently, much attention has been paid to expanding the range of shortening fats using traditional and non-traditional vegetable oils and fats, as well as their processed products in order to obtain finished products of increased quality and nutritional value.

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Shortenings have a unique property for food ingredients - wide possibilities for replacing one type of raw material with another in the production of many products. However, sometimes when replacing a certain oil with another in a given product, additional processing may be required, which can increase the cost of production to undesirable levels.

The needs of the food industry are met by the production of shortening in three forms: plastic, liquid (suitable for pumping) and granular (in the form of flakes, powder).

In connection with the above, scientific and practical research in the direction of creating new formulations for shortening fats is of great interest.

Taking this into account, for the preparation of shortening fats for specific purposes, interesterified fats obtained from the modification of linseed oil and high-hard soybean lard were used as a fat base [7,8,9,].

2 Materials and methods

Research on the production technology of shortening fats was carried out in laboratory and pilot production conditions. The main technological stages in the production of shortening fats were the preparation of raw materials and supplies, dosage and mixing, emulsification, crystallization, filling and packaging. The stages of preparation and production technology of shortening fats are presented in Fig. 1.

The main technological equipment for preparing shortening fats was a mixer equipped with heated and cooled devices. A general view of the vertical mixer is shown in Fig. 2.

The preparation of shortening fats in the specified installation was carried out as follows:

Obtaining the product in liquid form eliminated the crystallization operation; the product in a supercooled fluid state was shipped in appropriate containers.

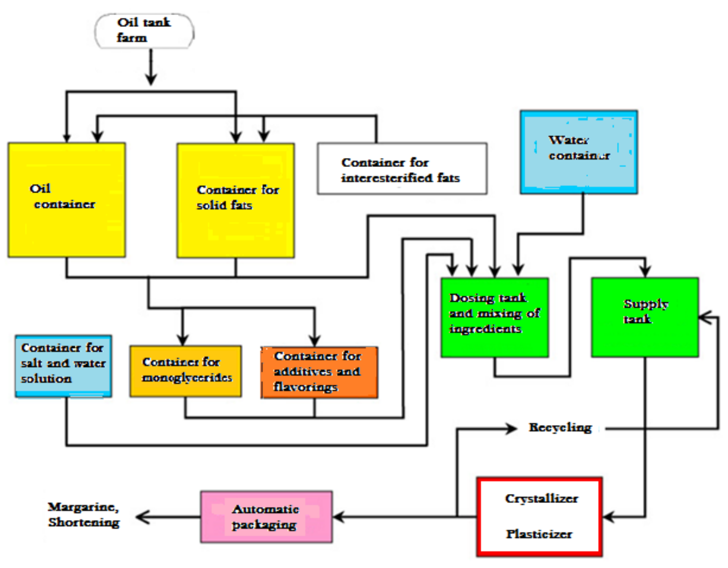
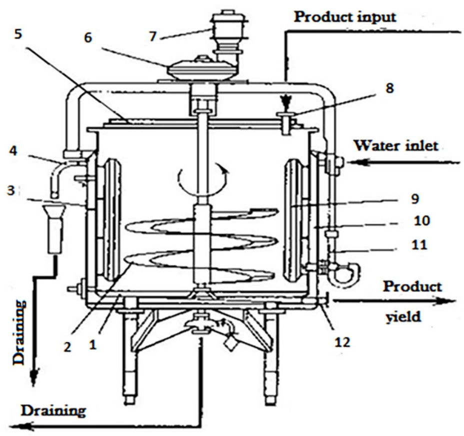


Fig. 1. The main stages and technology for the production of shortening fats.

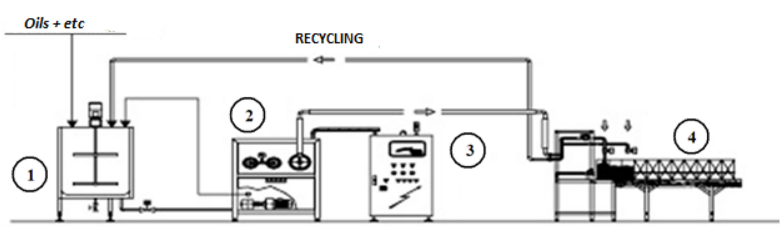


1-bottom, 2-mixer, 3-jacket, 4-pipe, 5-cover, 6-reducer, 7-electric motor, 8 fitting, 9-bumper, 10-housing, 11-level regulator, 12-pipe.

Fig. 2. Vertical cylindrical mixer.

Raw materials and materials were prepared and dosed separately. The laboratory mixer (Fig. 2) has a body 10 with a bottom 1, which has a slope towards the drain pipe 12. On the cover 5 there is a gearbox 6 and an electric motor 7, which are mounted on the frame. There is a fitting 8 for the input of raw materials and materials. Inside the cylindrical part there is a screw mixer 2 with a rotation speed of 59.5 rpm. Parallel to the generatrices inside the cylinder, bumpers 9 are attached, which do not allow the fat mixture to swirl as the mixer rotates. The mixer is equipped with a steam-water jacket 3 (water from the jacket flows through pipe 4) and a level regulator 11.

The preparation of shortening fats in experimental production conditions was carried out in the technological equipment of the margarine workshop (Fig. 3).



1- container with mixer; 2-shortening preparation unit; 3-regulator-dispenser; 4 packaging machine.

Fig. 3. A set of technological equipment for the production of shortening fats in experimental conditions.

3 Results and discussion

A new composition of fat shortening based on hydrogenated cottonseed oil with different iodine numbers has been proposed.

Shortenings are prepared in laboratory and experimental conditions using hydrogenated cottonseed oil and solid fats. The composition of shortening is given in Table 1.

Table 1. Composition of new types of shortening.

Name of fatty raw materials	**Content of components, %**						
	Plant raw materials			**A mixture of raw materials of animal and plant origin**			
Hydrogenated cottonseed oil, hh 80	90.0	–	–	–	–	–	91.0
Hydrogenated cottonseed oil, hh 88	–	88.0	–	–	–	89.0	–
Hydrogenated cottonseed oil, hh 96	–	–	–	35.0	–	–	–
Hydrogenated cottonseed oil, hh 109	–	–	–	14.5	–	–	–
RO palm oil	–	–	91.0	55.0	–	–	–
Solid animal fat	–	–	–	–	82.5	–	–
Hydrogenated cottonseed oil, T = 60	10.0	–	–	–	–	–	–
Palm oil, T = 56	–	12.0	9.0	10.0	–	–	–
Solid animal fat, T = 59	–	–	–	–	3.0	11.0	9.0
TSH content, % at:							
10.0°C	26	31		25		32	
26.7°C	20	20		18		21	
40.0°C	At least 9	11		10		At least 9	

Note. Ich -iodine number, rJ_2/100 g; RO-refined and bleached; T – titer, °C.

As can be seen from the data in Table 1. new types of shortening differed in the content and ratio of hydrogenated cottonseed oil and solid edible fats.

Shortenings have also been prepared from transesterified tallow and mixtures of linseed oil and transesterified tallow. (Table 2)

Table 2. Shortenings based on interesterified fats and their physicochemical properties.

Characteristic	**Shortening**	
	From interesterified fat, %	**Mixture of interesterified fat, %**
High oleic flaxseed oil	55.0	30.0
Solid fat from cottonseed oil, T = 60°C	–	–
Solid fat from soybean oil, T = 63°C	45.0	–
Interesterified fat	–	70.0
Modification process	Transesterification	
Physical and chemical indicators		
Dropping point in °C	33.4	30.4
10°C	27.5	20.0
15°C	20.0	13.0
20°C	18.2*	11.6*
25°C	16.0	10.0
35°C	11.0	8.0
Iodine number, g J_2/100 g	86.5	91.6

Induction period according to MAC, h	–	–
Total amount of saturated fatty acids, %, including	45.0	34.0
stearic	40.2*	30.0*
others	4.8*	4.0*
Content of trans isomers, %	2.0	2.0

* Estimated value.

Designations: ICN – iodine number, g J2/100 g; T – titer, °C; TTT – solid triglycerides; MAK – active oxygen method.

Data in Table 2. indicate that the fat products used have a unique property for food ingredients - wide possibilities for replacing one type of raw material with another in the production of many products.

Shortening was produced in three forms: plastic, liquid and granular (in the form of flakes, powder).

Plastic shortenings, that is, universal-purpose shortenings, were a mixture of solid fats and vegetable oils with a wide range of uses.

The resulting liquid shortenings were suspensions consisting of solid fat dispersed in liquid oil, usually in β crystalline form.

Flaked, granulated, or powdered shortenings consisted of refractory edible oils that were solidified into these forms for ease of transportation, faster melting, or to provide specific functions in the food product.

Some types of shortening were obtained immediately after plasticization without tempering. To ensure the required quality, some types of shortenings were tempered (Table 3).

Table 3. Composition and characteristics of shortenings for crispy pies.

Name of components	**Type of shortening**		
	from soybean oil		**from soybean and cottonseed oil**
	1	**2**	**3**
Hydrogenated soybean oil with NP 95, %	95	-	-
Hydrogenated soybean oil with NP 88, %	-	60	-
Hydrogenated soybean oil with NP 80, %	-	-	92
Hydrogenated soybean oil with 60% CN	-	40	-
Hydrogenated cottonseed oil with T=63°C	5	-	-
Hydrogenated cottonseed oil with T=60°C	-	-	8
Physico-chemical characteristics			
Crystal form TSH content, %, at:	β	β	β
10.0	25.0	34.0	26.0
21.1	15.0	25.5	18.0
26.7	13.0	22.5	16.0
33.3	10.0	13.5	10.0
40.0	7.5	4.5	6.0
Dropping point in °C	33.1	31.4	29.3

Note. IC-iodine number, rJ2/100 g; T-titer, °C; TSH-solid triglycerides.

Evaluation of the appearance and organoleptic characteristics of shortening fats was carried out using a scoring method.

The assessment results are shown in Table 4.

Table 4. Shortening Appearance Rating Scale.

Rating, points	Color*	Surface gloss	View of the texture on a cut				
			Visual assessment**	Presence of stains	Marbling	Smearable consistency	Liquid oil separation
10	**Absent**	**Ideal**	**Perfect**	**Absent**	**Absent**	**Absent**	**Absent**
9	Very weak	Very good	Very good	Very few, small	Same	Same	Same
8	Light shade	Good	Good	A little, small	-«-	-«-	-«-
7	Moderate shade	Average	Average	Numerous, small	Several small veins	-«-	-«-
6	Unacceptab le	Slightly dull	Bad	Very few, big	Many small veins	-«-	-«-
5	Same	Dim	Very bad	A little, big	Several large veins	-«-	-«-
4	-«-	Dim	Same	Numerous, large	Many large veins	Very mild	-«-
3	-«-	Very dim	-«-	Same	Same	Weakly expressed	-«-
2	-«-	Same	-«-	-«-	-«-	Same	Weak
-«-	-«-	-«-	-«-	-«-	-«-	Very pronounced	Weakly expressed

The produced universal shortenings were used to prepare baked goods.

Specialized shortenings for confectionery products consisted of lard and solid fats used in the production of universal shortening. Solid fats provided a flat melting curve, i.e. expansion of the range of plasticity and strength of products. However, an excessive amount of solid fat led to a decrease in the plasticity of shortening, as a result of which the process of its introduction into the product was difficult; the products no longer melted in the mouth so quickly [10,11,12]. Softer fats were sometimes used among hard fats (for example, hydrogenated cottonseed oil with an iodine value of 25 to 30), as this allowed them to be slightly increased in dosage compared to hard fats with a low iodine number (4.0 or lower). For the production of the most heat-stable products, the proportion of solid fats crystallizing in the β`-form ranged from 15 to 20% (Table 5).

Table 5. Composition and characteristics of shortening for filling cookies.

Name of components	Type of shortening				
	Palm oil with melting point, °C	Palm oil based mixtures	Hydrogenated oil blends	Solid fat mixtures	Selectively hydrogenated soybean oil

	24.5	31.4	33.1				
Palm kernel oil, %	100	-	-	69	-	-	-
Hydrogenated palm oil with CN 5,%	-	100	-	-	-	-	-
Hydrogenated palm oil with HP 1,%	-	-	98	-	-	-	-
Hydrogenated soybean oil with NP 66,%	-	-	-	25	-	-	-
Hydrogenated soybean oil with NP 74,%	-	-	-	-	78	-	-
Hydrogenated soybean oil with NP 80,%	-	-	-	-	20	75	-
Hydrogenated cottonseed oil with T=60°C	-	-	2	6	2	-	-
Solid animal fat	-	-	-	-	-	25	-
Soybean oil hydrogenated under special conditions with 75 pH	-	-	-	-	-	-	100
Physico-chemical characteristics TSH content, %, at:							
10.0	59	57	63	53	39	27	58
21.1	29	33	41	24	24	15	43
26.7	0	8	16	14	17	12	34
33.3	-	3	7	8	7	6	12
40.0	-	-	4	4	3	1	1
Dropping point in °C	29.1	31.4	33.1	34.3	31.2	30.6	29.3
Induction period according to MAC, hours, not less	200	200	200	200	100	75	200

Note. IC-iodine number, rJ2/100 g; T-titer, °C; TSH-solid triglycerides; MAC method of active oxygen.

Effective technology for producing shortening fats and optimizing the composition, as well as the ratio of the constituent components, requires the use of modern methods of mathematical processing of preliminary experimental results. Taking this into account, mathematical processing and optimization of the shortening fat formulation was carried out.

In the practice of research and quality control of oils and fats, one has to limit oneself to a small sample, i.e., a small number of observations or measurements, the number of which does not exceed 30, and often amounts to 3–4 repetitions.

Optimization of the recipe was carried out on the basis of a full factorial experiment (FFE) – 2k-1–1 with a fractional (1/2) replica. In this case, the following were selected as variable factors:

X1 – vegetable oil content, %;

X2 – solid fat content, %;

X3 – melting temperature of the fat mixture °C.

Table 6 shows the levels of variation of variable factors X1–X3.

Table 6. Levels of variation of variable factors X_1–X_3.

Variable parameter name	Designation	Unit change	Levels of variation	
			lower (-)	upper (+)
Vegetable oil content	X_1	%	45	70
Solid fat content	X_2	%	30	55
Melting point of fat mixture	X_3	°C	29	31

The following optimization criteria were selected: Y_1—resistance of fat mass at 0°C, hour and iodine value of solid fat, % J_2.

During mathematical processing, data was accumulated during the normal functioning of the shortening fat preparation technology. Taking into account the specific features of the production of shortening fats and the duration of laboratory tests made it possible to choose the interval between measurements equal to 2.0 hours. Computer processing of statistical data was carried out according to the algorithm presented in table 6.

Table 7. Mathematical descriptions of the optimization process for shortening fat formulations and assessment of their adequacy.

Name of production line	Mathematical description of the process	Estimated values of criteria		
		Cochran	Student's test	Fisher
Optimization of shortening fat formulation	$У_1= 6.3-1.7 X_1+ 0.475 X_2+0.525 X_3$	0.221	0.434	0.717
	$У_2= 113.49-2.94 X_1+ 0.99 X_2+ 1.36 X_3-1.19 X_1X_2X_3$	0.325	0.716	2.001

From Table 7 it is clear that the mathematical descriptions of Y_1 and Y_2, according to the values of the Cochran-Student and Fisher criteria, are adequate to the process under consideration.

Using equations Y_1 and Y_2, it is possible to predict the content of the ratio of vegetable oil and solid fat in the composition of shortening fat.

Moreover, the coefficients in equations Y_1 and Y_2 make it possible to determine the degree of influence of each factor and their interaction on the indicators of this process. The actual process for preparing shortening is based on vegetable oils and solid fats and can be used to optimize the final product formulation.

The influence of shortening fat on the physicochemical parameters of baked goods has been studied.

The dough was kneaded using straight methods. For the control sample of the bread product, the dough was prepared without adding shortening fat to the product, but with the addition of 5% sugar according to the recipe. Experimental samples of bread products were prepared using shortening fat. The amount of anhydrous fat added to the bread product was 3%, and sugar - 5% by weight of flour. The dough for test samples was prepared according to the following typical recipe (Table 8) to obtain comparative results, samples of bread products were also prepared using table margarine (OST 18-197-84). For comparison, a bread product was prepared with the addition of table margarine in an amount of 3.6 % by weight of flour, which in terms of anhydrous fat was also 3%.

Table 8. Recipe for preparing baked goods.

Name of raw materials	Amount of raw materials, g
Wheat flour	100
Salt	1.5
Pressed yeast	2.5
Sugar	5.0
Anhydrous fat	3.0
Water	By calculation[x]

(x) the amount of water was calculated taking into account the moisture content of the flour, based on the dough moisture content of 44.5%.

Comparative indicators of quality and physico-chemical characteristics of control and experimental samples of bread products with the addition of fat additives are given in Table 9.

The data given in Table 9 indicate a change in the quality indicators of the bread product depending on the quality and composition of shortening fat.

The quality of the prepared bread was assessed based on a set of indicators using a 100-point system.

Table 9. Comparative indicators of quality and physical and chemical characteristics of bread products using (3% by weight of flour) fat additives.

Bread quality indicators	Control (no fat)	Samples of baked goods with added fats	
		Margarine	Shortening fat, sample no.
Ud. volume, cm/100 g	375	432	461
Change beat. volume % to control	0	+13.7	+22.9
Porosity, %	72	75	77
N/A hearth bread	0.37	0.43	0.46
Structural and mechanical properties:			
N_{obsh}	91.8	114.7	131.1
N_{obsh}	69.5	85.3	97.8
Crumb moisture, %	44.0	43.9	43.9
Crumb acidity, N	2.2	2.1	2.1
Quality assessment based on a set of indicators, points	78	84	87

The data in Table 10 indicate that the use of shortening fats helps to increase the specific volume, improve the nature of porosity and structural and mechanical properties of the bread crumb compared to samples of products baked using margarine.

Table 10. The influence of lipids and shortenings on the volume of bread product (cm).

Lipids	Lipid dosage in %	Bread volume (cm)	
		Shortening	
		0% (control)	3 %
-	0	750	720
Unfractionated free lipids	0.8	775	885
Polar	0.2	925	925

Non-polar	0.6	700	815
Triclycerides	0.4	725	808
Diglycerides	0.2	733	815
Monoglycerides	0.1	738	875
Phospholipids	0.2	740	860
Glycolipids	0.2	890	-
Digalactose diglyceride	0.2	875	935
Monogalactose glyceride	0.2	890	895

Bakery products were produced according to the technological regime and recipe adopted in a small enterprise, in accordance with approved technological instructions, as well as taking into account the moisture content of the fat product used. Under experimental conditions, wheat flour 1 s. was used. with the following characteristics:

- humidity, % - 1.37, amount of raw gluten, % - 30, acidity -30 N, ash content, % - 0.65.

The dough for Patyr flatbreads was prepared using the sponge method, using a classic dough. The dough and dough were kneaded in batch mixing machines “Standard”. Fermentation of the dough and dough took place in bowls. The finished dough was cut using a dough divider brand A2-XTH. Layering of dough pieces rounded in a rounder was carried out in an A2-XPA brand proofing oven at an air temperature of 35-370 C and a relative humidity of 75%. After proofing, each piece of dough was manually shaped into a round cake and the surface of the cake was pierced with a chekish. Dough pieces for patyr were smeared with egg emulsion to obtain gloss before being placed in the oven. Baking was done in FTL-2 ovens, on heated perforated metal sheets of the oven cradles, as well as in special hot ovens - tandoors. Patyr was baked at a temperature of 240-250^{0}C.

During the development of products, it was found that the use of shortening fat does not have a negative effect on the physical properties of the dough.

Comparative data on product quality indicators are presented in Tables 11 and 12.

Table 11. Quality indicators of bread products produced in the FTL-2 oven.

Quality indicators	Unit change	Product samples	
		Patyr 1 s., 0.4 kg	
		Control*	Experience 1
Humidity	%	40	40
Acidity	H	2.5	2.5
Specific volume	cm/100		
Swellability of the crumb through:			
3 hours		42	45
16 hours		40	42
24 hours		39	40

Table 12. Quality indicators of bread products produced in special tandoor ovens.

Quality indicators	Unit change.	Product samples	
		Patyr 1 s., 0.4 kg	
		Control*	Experience 1
Humidity	%	40	40
Acidity	H	2.5	2.5
Specific volume	cm/100	220	
Swellability of the crumb through:			
3 hours		48	48
16 hours		45	45

24 hours		42	43

From these tables it can be seen that products produced with the addition of shortening fat are not inferior in quality to control samples, and in some respects they were better.

A tasting assessment of the baked products showed that in terms of certain organoleptic indicators, the quality of the products produced with the addition of experimental samples of shortening fat was not inferior, and in terms of the consistency of the crumb of the product during storage, it was slightly superior to the control samples of the product.

4 Conclusion

Cottonseed, soybean and palm oil, as well as their processed products, are acceptable fatty raw materials for the production of shortening fats used for the preparation of target products.

Shortening fats are characterized by crystal formation, which is a characteristic of the formation of the final product.

The tempering characteristics of fat shortenings make it possible to reveal their technological properties for use in the production of margarine and bakery products.

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