UDC 641.5:663.347.8
DOI: 10.15587/1729-4061.2021.246006

DETERMINING PATTERNS IN THE FORMATION OF FUNCTIONAL-TECHNOLOGICAL PROPERTIES OF A FAT-BASED SEMI-FINISHED PRODUCT IN THE TECHNOLOGY OF SPONGE CAKE PRODUCTS

Aliona Dikhtyar
Corresponding author
PhD, Senior Lecturer*
E-mail: alenadikhtyar@ukr.net
Svitlana Andrieieva
PhD, Associate Professor*
Natalia Fedak
PhD, Professor*
Olga Grinchenko
Doctor of Technical Sciences, Professor*
Yevgen Pyvovarov
Doctor of Technical Sciences, Professor*
* Department of Food Technology in the Restaurant Industry
State Biotechnological University
Alchevskykh str., 44, Kharkiv, Ukraine, 61002

This paper reports the development of a technology for a fat-based semi-finished product, which was used in the manufacturing of products made from butter sponge-cake batter. When combining high-oleic type oils, beeswax, and monoglyceride, the dense emulsion "oleogel" is formed, which can replace fatty products in flour products technology. The fat-based semi-finished product devised fully matches the technological functions of margarine.

The expediency of using sunflower oil of high-oleic type (90.0 %) was established, as a base for the fat-based semi-finished product, as well as the rational percentage of organogelators (monoglyceride, 7 %, beeswax, 3 %), which would ensure the production of a fat-based semi-finished product for the target purpose.

The feasibility of using a fat-based semi-finished product has been determined in order to solve two tasks: the introduction of a fat-based semi-finished product that contains high-oleic sunflower oil and has several functional benefits of a healthy diet. The fat-based semi-finished product devised could replace butter in the butter sponge cake technology.

It was established that the use of the fat-based semi-finished product ensures the production of products from sweet dough, characterized by the highest values of specific volume and porosity. Applying the fat-based semi-finished product makes it possible to increase the yield of finished products (shrinkage decreases by 19.5 % compared to the control sample, to 18.4 %). The parameters for storing finished products from sweet dough containing the fat-based semi-finished product have been substantiated. It was determined that intensive fat release begins on day 7 of storage of finished products. After 10 days of storage, the experimental samples of sponge cakes release 2.0 times less fat than the control sample.

The technology for making products from sweet dough using the fat-based semi-finished product has been developed

Keywords: high-oleic type oil, fat-based semi-finished product, sponge-cake batter products, beeswax

Received date 08.10.2021
Accepted date 29.11.2021
Published date 28.12.2021

How to Cite: *Dichtyar, A., Andrieieva, S., Fedak, N., Grynchenko, O., Pyvovarov, Y. (2021). Determining patterns in the formation of functional-technological properties of a fat-based semi-finished product in the technology of sponge cake products Eastern-European Journal of Enterprise Technologies, 6 (11 (114)), 15–31. doi: https://doi.org/10.15587/1729-4061.2021.246006*

1. Introduction

In flour confectionery, sponge-cake batter products occupy a significant place as their attractive consumer properties predetermine a constant demand for them. Confectionery production has demonstrated a steady growth in recent years, which analysts attribute to an increase in their consumption. A special role in the range of flour confectionery belongs to those based on a sponge cake semi-finished product. They are characterized by an attractive physical appearance, pleasant taste, aroma, and consistency.

In terms of consumption, confectionery is ranked eighth in the world. Most of it is flour confectionery (6 kg per capita per year), 41 % of which account for sponge-cake batter products. Sponge cake is quite popular in several European countries (Italy, Spain, Belgium). Most of it is consumed in Belgium (16 kg per capita per year) with an average in Europe of 8.8 kg [1–3].

Along with this, the production of sponge cake semi-finished products faces some issues related to improving their quality and consumer value, expanding the range of these products, effective utilization of the potential of raw materials, intensification of the technological process, etc.

It is possible to enhance the level of competitiveness of these products by devising highly efficient technologies that would provide for high-quality products without increasing their cost.

That puts forward certain requirements for the ingredient composition and technologies of food products, which must be investment-attractive and competitive. Therefore, it also refers to the production of sponge-cake batter products, in particular butter sponge cake, whose volume of production and consumption has been growing significantly in recent years. The use of butter in their composition as a fatty component, as well as the hydrogenated vegetable oils that are costly, unsatisfactory fatty acid composition, the limited shelf life of products based on them do not meet the requirements of manufacturers. Thus, it is advisable to consider the value of fat in the technological process, taking into consideration such criteria as the raw materials, physiology, technology.

Margarine, confectionery, and other sectors of the food industry experience a significant need for fats, characterized by a narrow range of hardness, melting temperatures, and other structural, mechanical, and physicochemical characteristics. For example, devising a sponge cake semi-finished product is impossible without the use of solid fats with certain physicochemical and structural-mechanical properties, including the application of tropical fats (palm, palm kernel, and coconut oils). Manufacturers of fatty products face an alternative whether to use fats with a large amount of trans fats for these types of products, or apply solid fats of biogenic origin whose price is affordable, that is, tropical fats. The use of tropical fats makes it possible to obtain products with the predefined characteristics. The properties of the fatty phase (which includes, among other things, fractionated tropical fats) of these products affect some of their important indicators, namely thermostability, product shine, fragility, hardness, refractoriness.

One of the ways to tackle the replacement of trans fats is the use of tropical fats in their natural form, the application of individual fractions obtained by physical methods. In this case, there is an issue related to the significant use of refractory fats. That predetermines the need to replace them with liquid vegetable oils. However, the simple replacement of saturated fats with liquid oils does not give the desired result in most cases. In this regard, it is required to devise a project of a fat-based semi-finished product technology for butter sponge-cake semi-finished product.

2. Literature review and problem statement

The task of improving the quality and nutritional value of sponge-cake semi-finished products must be addressed simultaneously with the issue related to extending their shelf life in fresh form. When storing sponge cakes, their plasticity and elasticity decrease, their hardness and fragility increase, the taste deteriorates, which is due to changes in the state of starch and proteins.

The range of products based on sponge-cake batter is quite wide due to the use of traditional and unconventional raw materials [4]. However, the demand for sponge-cake products, despite the expansion of the range, remains unmet, partly due to the complexity of the production process of manufacturing these products according to the traditional scheme.

In its structure, sponge-cake batter is a highly concentrated dispersion of air in the medium, which consists of egg products, sugar, flour, which is why the sponge batter is referred to as foam. Research on the search for new types of sources of environmentally friendly raw materials, which has high technological characteristics and has preventive properties, is underway in different areas. Most of it involves the use of natural, mainly plant-based sources of raw materials containing, along with indispensable food substances, other physiologically valuable minor, and biologically active substances.

Work [5] proposed the technology of sponge-cake batter, which involves adding various types of flour to the recipe. The formulation consists of mixtures of wheat flour, pumpkin cake flour, melon, and milk thistle in the ratio of (80...50):(30...10):(20...10), which ensures the improvement of the quality and consistency of products, extends their shelf life. However, the considered technique of improving the technology of sponge-cake batter is not widely implemented due to the lack of raw material base for certain types of raw materials.

The authors of [6], in order to control the safety of developed sponge cakes made from organic raw materials according to the principles of the HACCP system, two recipes of the sponge cakes “Winter Pleasure” and “Exotic” were devised. The preparation of the sponge-cake semi-finished product “Winter Pleasure” involved organic buckwheat flour, ground organic ginger, organic maple sugar, organic eggs, organic mint essence. The preparation of the sponge-cake semi-finished product “Exotic” involved organic flour from spelt, organic hemp flour, organic rosehip powder, organic coconut sugar, organic eggs, and essence based on organic lemon. It was established that the products devised have high organoleptic properties while the determined microbiological and toxicological indicators of the safety of finished products do not exceed the permissible limits. However, the issues related to prolonging the shelf life of developed sponge cakes remained unresolved.

Consistency improvers are used mainly in the production of food products with unstable consistency and homogeneous structure. Most thickeners and gel forming agents with the status of food additives belong to the class of polysaccharides (glycans) [7].

In [8], several sponge cake production technologies were developed by using traditional technology and applying xanthan gum, which acts as a stabilizer and regulator of sponge-cake batter rheology. The authors replaced part of the mélange with egg powder mixed with xanthan gum as moisture-binding agents. Thus, that technology made it possible to extend the shelf life of products by three days. However, that advancement, first of all, provides products with biological value and dietary properties and, to a lesser extent, improves foaming properties and stabilizes the structure of sponge batter.

An option to overcome the corresponding difficulties may be the use of xanthan gum, sodium alginate, and gelan gum, which are the most common dietary supplements that are involved in the formation of the structure of sponge-cake batter and have the necessary technological properties. These substances can form stable structured systems and improve the structural and mechanical indicators of finished products [9].

Paper [8] examines the main directions of using various structure-forming agents in food products. Data on the gel-forming ability of apple pectin compared to xanthan gum are given. The authors considered the possibility of using xanthan gum in the production of flour confectionery products as an agent that slows down the processes of starch retrogradation. That occurs due to the protein-carbohydrate and protein-lipid interaction that emerges when using xanthan gum and egg powder during the kneading and baking of sponge cakes. It was established that sponge-cake semi-finished products that were baked using xanthan gum had a delicate structure and a flat surface of the baked semi-finished product. Partial replacement of mélange with egg powder and xanthan contributes to greater crumbliness and tenderness of products, slightly affecting the porosity and height of the product. Increasing the amount of water significantly improves the quality of the biscuit semi-finished product. However, the proposed technology reduces the biological value of finished products.

Paper [10] reports the results of devising sponge-cake technology using modified fruit-oligosaccharides. The cited paper shows that the palmitic esters of fruit-oligosaccharides (1...2 % of the cupcake weight) are used as emulsifiers that improve the aeration and emulsification of components, technologically reduce cooking time, and improve the structural and mechanical properties of sponge cakes. However, the cited study does not analyze the dynamics of changes in the devised products made from sponge-cake batter during storage. In addition, the emulsifier has prolonged shelf life, which requires additional refrigeration equipment in production.

The review of the features of sponge-cake batter preparation [11–13] shows that it is a complex foam-like system that is capable of rapid destruction and needs to increase its stability. This requires a detailed consideration of the scientific principles of changing the recipe composition and adjusting the physicochemical parameters for manufacturing sponge-cake semi-finished products.

Taking into consideration the critical points and disadvantages of the manufacturing process of sponge-cake semi-finished products, the basic directions for the development of sponge-cake semi-finished products technology have been determined:

– enhance the foaming ability and foam stability of the whipped mass in order to improve the quality of products;

– intensify the process of obtaining the foam-like structure of sponge-cake batter;

– reduce the content of calories and increase the biological value of sponge-cake semi-finished product, provide it with dietary properties;

– expand the range of sponge-cake products by adjusting their recipe composition;

– inhibit the processes of staling and prolong the shelf life of products.

Fats regulate the degree of swelling of flour colloids, adsorbing on the surface of colloidal particles, weaken the mutual relationship between them, and prevent the penetration of moisture, increasing the content of the liquid dough phase, as a result of which the dough becomes more plastic. Thus, fats, while reducing the swelling of flour colloids, increase the plasticity of the dough; the finished products are given layering, crumbliness, and porosity. As the amount of fat increases, the dough becomes looser and brittle. Thin films of fat and its high content in dough provide a porous and fragile structure of finished products.

Fat-acid composition of fat and its physical condition significantly affect the quality of confectionery products. Fats used in confectionery technology must be plastic. If the melting point of fat exceeds the temperature of the dough, then it remains in the dough in the form of particulate particles, its positive effect on the properties of the dough decreases. The use of liquid oils in sponge-cake batter leads to an increase in the density of the dough and, as a result, to a deterioration in the structural-mechanical properties of the finished products. Given the above, it has been established that fats that retain plasticity in a wide temperature range have an advantage.

Thus, when choosing a fat component to make sponge-cake batter products, it is necessary to take into consideration its functional and technological properties and correctly calculate its content. Among the most significant indicators is their fatty acid composition (the ratio of saturated and unsaturated fatty acids), which determines the hardness of fat, its plasticity, and resistance to oxidation processes.

If the content of saturated fatty acids is very high, then the dough will be hard, and its aeration will be low. Conversely, if the content of saturated fatty acids is very low, during stirring there is no saturation of the dough with air; as a result, we obtain a bonding structure of the dough, and the baked product will be of low quality.

Adjusted fatty acid composition (solid particle content) and β´-crystalline polymorph have been shown to provide optimal fat melting point [14]. That is, fat should be plastic, smooth, not grainy, keep its shape at room temperature, but should be easy to deform when using force.

Fat plasticity is a function of the fatty acid composition (solid particle content) and crystalline structure. That is, to ensure the quality of sponge-cake batter products, a prerequisite for choosing fat is a moderate content of solid particles and β´-crystalline polymorph stored in a certain temperature range. No less important indicator of the quality of fats is their resistance to oxidation processes under the influence of technological factors, which predetermines the shelf life of finished products. Factors influencing the degree of oxidation of fats are fatty acid composition, the presence of antioxidants, the conditions for processing and storage of fat-containing raw materials [15].

Consequently, fat with a balanced fatty acid composition (content of saturated and unsaturated fatty acids), with a certain content of antioxidants, solid particles, and β´-crystalline polymorphs is the key to high-quality sponge-cake batter products and, as a consequence, consumer health.

Currently, there are many recipes for making sponge-cake batter products that involve fatty raw materials [16]. The most common fatty raw materials to produce sponge-cake batter are margarine, shorting, and spread, but it should be noted that these fats contain a significant amount of saturated fatty or trans fatty acids. Numerous studies have established the negative impact of the latter on the human body. Therefore, the task of today is to minimize the content of these compounds in food. To this end, specialists increasingly prefer vegetable oils. However, this replacement is not always advisable since many technologies cannot be implemented without the use of solid fats.

Thus, the food industry needs to find and implement alternative types of fats that would be characterized by a high content of unsaturated fatty acids, vitamins, antioxidants, and would not contain trans isomers of fatty acids.

An option for overcoming appropriate difficulties may be the development and use of oleogels (organogels), conceptually new products that meet the requirements for healthy eating.

Oleogel is a three-dimensional, independent, thermally reversible, water-free, viscoelastic gel. Organogel meshes can be formed in two ways. The first is the classical formation of the gel mesh by polymerization. This mechanism converts the initial solution of monomers with various reaction-capable areas into polymer chains, which are converted into a single covalent-bound mesh. At a critical concentration (the gel point), the polymer mesh becomes large enough, so that in the macroscopic decomposition it begins to display gel-like physical properties: a large continuous solid mesh, with fixed and solid-like rheological properties [17]. However, oleogels, which are "low molecular weight gelators", can also be considered as a source of formation of gels due to their ability to self-group. Secondary forces, such as Van der Waals or hydrogen bonding, force monomers to group into an inconsequentially bound mesh that retains an organic solvent, and, as the grid increases, it exhibits the physical properties of the gel [18]. Both mechanisms of gel formation lead to the formation of gels, which are characterized as oleogels.

Oleogels are interesting products that are used for structuring food oils in order to obtain fat-based semi-finished products for target purposes [19].

Since oleogelization (gel formation) does not cause changes in the fatty acid composition of the final product, does not lead to isomerization and the formation of trans fats, this method is advisable for devising a fat-based semi-finished product for sponge batter. However, it should be noted that the crystalline structure formed during oleogelation can provide proper rheological and organoleptic properties of the fat-based semi-finished product, namely: uniformity of texture, creaminess, softness, aeration, plasticization, aftertaste [20].

The authors of [21] proved the expediency of using olive oil in the production of oleogels as sources of polyunsaturated and monounsaturated fatty acids. This technology involves the production of oleogels based on olive oil, Carnauba wax, and monoglycerides. The developed oleogels can be used for smearing on bread, as an alternative to butter or margarine, in order to promote a new form of olive oil consumption. It should be noted that the authors have not studied the feasibility of using this oleogel in the technology of confectionery. In addition, that technology is complicated by the fact that carnauba wax is an imported raw material.

The basic requirements for oil [22, 23] as the base of a fat-based semi-finished product:

– safety;
– affordability
– efficiency;
– low price.

The authors of [24] investigated the rheological properties of olive oil monoglycerides in the oleogel, in particular the deformation of the oleogel, and established the shear stress limit. Analysis of the morphology of olive oil monoglycerides in the oleogel revealed needle crystals with a length of 5...15 μm [25]. Olive oil oleogel was also made with a β′-lactoglobulin cross-link, an oil-in-water emulsion stabilizer. It was established that impurities in olive oil cause indigenous cross-linking with protein, which prevents protein rehydration.

Work [26] reports the comparative analysis of oleogel with mono- and diglycerides. It has been shown that the desired macroscopic properties could be adjusted according to the oleogelator concentration, while dynamic modules could be changed by modifying the ratio of the mixture of saturated and unsaturated fatty acid.

The authors of [27] investigated the properties of oleogel based on olive oil with the addition of different amounts of polycosanol (a mixture of long-chain alcohols extracted from vegetable waxes) and various tempering conditions. It has been shown that the initial crystallization temperature increases nonlinearly with the concentration of polycosanol; a fractal model has been built to study changes in a given system during storage depending on the concentration of the oleogelator. In [27], the authors developed an oleogel based on olive oil and polycosanol with the addition of ferulic acid as an active agent. Studies on digestion *in vitro* have proven well assimilation and excretion of oleogels from the body.

Saturated monoglycerides are studied as oleogelators in various oils. Similarly, the addition of Carnauba wax (E 903) in a minimum amount of 3...5 % was investigated in detail for gel formation, which was used as an organogelator in salad oil [15], and in soybean oil [28].

Analytical studies have established [29] that oleogels include organogelators, in particular fatty alcohols, saturated fatty acids, fatty acid hydroxides, monoglycerides, lecithin, waxes and wax esters, some polymers, and other compounds.

For use in the food industry, oleogel must be food-specific, safe, effective at the lowest concentrations, available at a low price. Among others, plant and animal waxes correspond best to these parameters [30].

The authors of [31] investigated the possibility of using oleogels in various foods, including confectionery, as an alternative replacement for shorting or margarine. The prospects of using oleogels using monoglycerides compared to universal shorting in the production of cookies were also studied. The cited studies have shown that the quality of cookies based on shortening is higher compared to oleogel-based cookies containing monoglycerides.

The authors of [32] explored the prospects of using an oil-water-cellulose emulsion in cookie production technology. It was established that the technology, subject to the use of an emulsion based on oil-water-cellulose, makes it possible to reduce the level of fatty raw materials by 33 %; but, during tasting, the samples of cookies based on an emulsion were estimated low in comparison with control.

The structural, mechanical, and organoleptic properties of cookie samples based on liquid fatty hydrochloride mixtures were studied in paper [33]. It was found that the cookie samples based on a mixture of oil with xanthan are characterized by greater elasticity and resistance to crumbling. In addition, cookies based on margarine and a mixture of oil with xanthan had a high sensory estimate.

In [34], the authors studied the prospects of replacing margarine in the technology of sponge cake with an emulsion (sunflower oil, water, and cellulose). It is noted that the addition of an emulsion in minimal quantities leads to an increase in deformation and structural stabilization of the dough.

Additionally, the prospects of using oleogel as an alternative structure-forming agent in the dough for sponge cakes were studied. Oleogel-based samples were found to be indistinguishable from control and demonstrated high quality indicators [35].

It is determined in [36] that the implementation of the technological process of production of sponge-cake batter products significantly depends on the technological properties of the fat component, which affects the nutritional value, rheological, structural-mechanical, and physicochemical properties of finished products. It has also been analytically established that at present the range of fats and fat products that do not contain trans fats is limited. At the same time, it is determined that the promising segment of fatty products are oleogels.

As noted above, the mechanism of oleogel formation was tackled in many studies. However, there is no oleogel intended for use in sponge-cake batter technology. All this gives reason to assert that it is advisable to conduct a study on the development of a targeted fat-based semi-finished product (oleogel) for sponge-cake batter products.

3. The aim and objectives of the study

The purpose of this study is to determine the patterns of formation of the functional-technological properties of the fat-based semi-finished product, which would enable its use in sponge cake technology.

To accomplish the aim, the following tasks have been set:

– to scientifically substantiate the technological parameters for making a fat-based semi-finished product for sponge-cake batter products;

– to investigate the physical and chemical indicators of model samples of the sponge-cake semi-finished product using the fat-based semi-finished product;

– to devise a recipe composition and technological scheme to produce sponge-cake batter products using a fat-based semi-finished product.

4. The study materials and methods

In the study, we used the following:

– sunflower oil of the high-oleic type (SOHO) according to TU U 15.4-13304871-007:2006; beeswax (VB);

– monoglyceride (MG);

– a fatty semi-finished product based on sunflower oil of the high-oleic type,

– beeswax and monoglyceride;

– model samples: sponge-cake batter containing the devised fat-based semi-finished product and margarine (control);

– the baked semi-finished product made from sponge-cake batter using the devised fat-based semi-finished product (oleogel);

– the baked semi-finished product made from sponge-cake batter using margarine;

– finished products made from sponge-cake batter using the devised fat-based semi-finished product (oleogel).

The new fat-based semi-finished products (oleogel) was obtained on the basis of the high-oleic sunflower oil; beeswax and monoglyceride were used as a structuring agent. The resulting oleogel was characterized by thermal reversibility in terms of organoleptic indicators.

The raw materials used for the production of semi-finished products and finished sponge-cake batter products using the fat-based semi-finished product met the requirements set by the acting regulatory documents.

In order to determine the structural and mechanical properties of sponge-cake batter and the baked products made from it, the dough samples were prepared with the addition of margarine (control) and a new fat-based semi-finished product, in line with the same technology.

Sampling for our research complied with GOST 23676-79, GOST 5904-82, GOST 5471-83, DSTU ISO 5555:2003, DSTU 4349:2004 (ISO 5555:1991, NEQ).

The melting point of internal fat was determined by the gradual melting of fat frozen in the capillary registering the melting point of fat.

The content of solid fat fractions in oleogel and margarine model samples was determined using the Minispec Bruker NMR-analyzer mq20 (BrukerOptics, Inc.). To this end, the samples were first completely melted in a water bath at a temperature of 90 °C, then 3.5 ml of each sample was selected in the NMR tubes and cooled in a water bath at a temperature of 0 °C for 1 hour. After that, the test tubes were cooled at a temperature of 20 °C for 30 minutes; we recorded the data acquired.

The fat-retaining capacity (FRC) was calculated according to the following formula:

$$FRC = \frac{(c-b)}{(b-a)} \times 100\,\%,$$

where a is the mass of an empty centrifuge glass, g;

b is the mass of a glass with a sample after centrifugation and draining of liquid, g;

c is the mass of a glass with a prototype of plant origin and fat (milk or vegetable) before centrifugation, g.

We determined the peroxide number of samples according to DSTU ISO 3960-2001. The essence of the method is to dissolve a certain mass of oil in a mixture of solvents, followed by titrating the existing hydroperoxides with a solution of sodium thiosulfate. It is calculated through the subsequent processing of the results and determining the peroxide value of oil (PN), mmol/kg:

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

V is the volume of sodium thiosulfate solution in the main experiment, cm^3;

V_0 is the volume of sodium thiosulfate solution in the control experiment, cm^3;

c is the concentration of sodium thiosulfate solution, mol/dm^3;

m is the mass of the prototype, g.

We determined the density of oil samples in accordance with DSTU 4633:2006.

The physicochemical properties of the baked sponge-cake batter products. The color of the surface and crumb of the sponge cake samples was determined at the colorimeter HunterLab UltraScan XE, USA.

We determined the fat content in the baked sponge-cake semi-finished product according to DSTU 7577:2014. The essence of the method is to extract fat from the product with organic solvent in the Soxhlet apparatus, evaporate the solvent, and determine the mass of extracted fat or skimmed residue, followed by calculating the mass fraction of fat as a percentage.

The degree of fat migration (DFM) from the samples was determined in accordance with the standard procedure [24, 30]. The samples of the baked sponge-cake batter were placed in cylindrical containers (diameter 60 mm) with filter paper (diameter 110 mm). The amount of fat lost by each sample was determined by the difference in the mass of the filter paper before and after placing it within 1, 7, and 10 days after the preparation of the samples at 20 °C. The experiment was repeated four times, and then we determined the average value with a standard error. The degree of fat migration (DFM) was determined in % (g of fat/100 g of sponge cake sample).

To calculate the amount of saturated and unsaturated fatty acids, we used the method of determining the fatty acid composition, which was based on the transformation of triglycerides of fatty acids into methyl esters of fatty acids and gas-chromatographic analysis of the latter.

The study was carried out at the rotary viscosimeter "Reotest-2" on the cylinder system S, S_3 at a temperature of 20 °C. The shear stress and viscosity were calculated from formulas for the corresponding values of shear rate.

The shear stress τ_r was determined as:

$$\tau_r = z \times a,$$

where z is the cylinder constant, dyn/cm^2;

a is the value of the scale at the device.

The effective viscosity η was determined as:

$$\eta = \frac{\tau_r}{D_r \times 100},$$

where η is the effective viscosity, Pa·s;

τ_r is the shear stress, dyn/cm^2;

D_r is the shear rate, sec^{-1}.

The coefficient of shape stability of the model systems of the baked products from sponge-cake batter using various fat bases at changes in the recipe components was measured as follows. The samples studied were molded in the form of a cylinder with a height of $1 \cdot 10^{-2}$ m with a diameter equal to height, and investigated the change in the height relative to the diameter (that is, the ability to keep the shape) for 5×60 s.

The humidity of the baked semi-finished products was determined by drying to a constant mass.

The mass of the semi-finished products was determined by weighing on technical scales with an accuracy of up to 0.01 g.

The volume of the semi-finished products was found by immersing the sample into the measuring cylinder, which is filled with millet – from the difference in the volume of the millet with a sample and the millet as is.

The specific volume ($V_{specific}$, m^3/kg) of the samples baked from sponge-cake batter was calculated as:

$$V_{specific} = \frac{V}{m}, \text{ m}^3/\text{kg},$$

where V is the sample volume, m^3,

m is the sample weight, kg.

We determined the porosity of samples according to the standard procedure using a Zhuravlev device (according to GOST 5669-96*). From the crumb of the piece at a distance of at least 1 cm from the crust, one makes the notch by the cylinder of the device; to this end, a sharp edge of the cylinder, pre-lubricated with vegetable oil, is injected with rotational movement into the crumb of the piece. The cylinder filled with the crumb is laid on the tray so that its rim enters the opening that is in the tray. Then the sponge cake crumb is pushed out of the cylinder with a bushing, about 1 cm, and cut it on the edge of the cylinder with a sharp knife. The cut piece of the crumb is removed. Remaining in the cylinder, the crumb is pushed out with a ferrule to the wall of the tray and also cut off at the edge of the cylinder.

To determine the porosity of samples, three cylindrical samples are taken, the volume of (27±0.5) cm^3 each. Prepared samples are weighed simultaneously.

Porosity, P, %, is calculated as:

$$P = \frac{V - \frac{m}{p}}{V} \times 100, \%,$$

where V is the total volume of samples notches, cm^3;

m is the mass of notches, g;

p is the density without the porous crumb mass.

The humidity of the dough was determined by drying to a constant mass according to the following formula [84]:

$$W = \frac{a - b}{(a - c)} \times 100, \%,$$

where a is the mass of the container with a batch before drying, g;

b is the mass of the container with a batch after drying, g;

c is the mass of an empty container, g.

The baking shrinkage (BS) of products was calculated as:

$$BS = \frac{(W_d - W_{\text{r.p.}})}{W_d \times 100}, \%,$$

where S is the baking shrinkage, %;

W_d is the dough weight, g;

$W_{r.p.}$ is the weight of the resulting product.

The drying shrinkage (DS) of the semi-finished products was calculated as:

$$DS = \frac{(W_{\text{f.b.s.m.p.}} - W_{s.s.f.p.})}{W_{\text{f.b.s.m.p.}} \times 100}, \%,$$

where DS is the drying shrinkage, %;

$W_{\text{f.b.s.f.p.}}$ is the weight of a freshly baked semi-finished product, g;

$W_{\text{s.s.f.p.}}$ is the weight of the stored semi-finished product, g.

The shape stability is characterized by the value of the ratio of height (H) to diameter (D). The diameter and height of the semi-finished products were determined using a measuring ruler with millimeter divisions. To this end, a semi-finished product was cut in diameter into two equal parts and measured the height and diameter of these parts in the largest places of incision.

The structural-mechanical properties (hardness and adhesion) of the samples of the fat-based semi-finished product were determined with the help of the texture analyzer TA-XT2i (Stable Microsystems, Surrey, Great Britain), equipped with a block and conical acrylic probe with an angle of 45° and texture exponent v.6.1.0 software package (Stable Microsystems) [21].

Using the penetrometer "Labor", we determined the compression, elasticity, plasticity of the crumb of the developed samples of baked products from sponge-cake batter. The research was carried out at a constant penetration effort (the depth of immersion was determined).

Based on the data, we calculated the shear stress limit (σ_0) of the non-destroyed structure from the Rehbinder formula:

$$\sigma_0 = k \frac{m \cdot g}{h^2},$$

where m is the mass of the indenter and the rod of the device, kg;

g is the acceleration of free fall, m/s^2;

h is the cone dive depth, m;

k is the indenter constant.

The organoleptic assessment of the quality of the new fat-based semi-finished product and sponge-cake batter products on its basis was carried out by analytical methods and the method of profile analysis. The method of profile analysis involves the use of a set of descriptive terms (descriptors) to evaluate individual organoleptic indicators of the product (smell, consistency, taste, etc.) according to the scheme: determining the characteristic features of indicators, the degree of their intensity, the order of detection. By the quantitative estimation of the size of the selected descriptors on a given scale, we built the profiles of organoleptic indicators in the form of a diagram.

5. Results of studying the technological properties of the fat-based semi-finished product for sponge-cake batter products

5. 1. Substantiation of technological parameters for making the fat-based semi-finished product for sponge-cake batter products

In order to determine the optimal fat base (vegetable oil) for the development of a fat-based semi-finished product, it was considered advisable to compare the characteristics of vegetable oils.

Since olive oil is mostly used as a base for oleogels, it was considered advisable to choose oil with similar properties and compare their characteristics. To this end, we chose the high-oleic sunflower oil and the sunflower refined deodorized oil (SRDO).

The results of the study of physicochemical parameters are given in Table 1.

Table 1

Comparative characteristics of the composition and physicochemical parameters of oils

Physicochemical parameters	Oil type		
	SOHO [37]	SRDO [37]	Olive oil [37]
Density ρ, kg/m, at t=20±2 °C	915...920	915...918	916...918
Viscosity η, Pa·s, at t=20±2 °C	0.0180±0.0009	0.0175±0.0009	0.0180±0.0009
Freezing point t, °C	0...–6	–16...–19	0...–6
Iodine number, IN, % I_2	105±5	119±6	89.9±5
Acid number, AN, mg KOH/g	0.112±0.003	0.330±0.009	0.198±0.006
Peroxide number, PN, mmol ½ O/kg	0.83±0.02	2.00±0.06	0.98±0.03
Saponification number, SN, mg KOH	184...194	186...194	185...200
Thiobarbituric number, Tb.N, mg MA/1,000 g, at wavelength λ=535±10 nm,	0.0100±0.0003	0.0200±0.0006	0.0100±0.0003
Extinction coefficient, $E_{1cm}^{1\%}$	3.00±0.09	3.60±0.10	4.20±0.12

Table 1 illustrates that SOHO is very similar to olive oil in its physicochemical properties and fatty acid composition, as evidenced by data in Table 2.

The experimental oil samples differed mainly in the content of palmitic (C16:0), stearic (C18:0), oleic (C18:1), and linoleic (C18:2) acids. At the same time, SOHO contains 7.6 % less, and SRDO (control) contains 4.7 % less palmitate compared to olive oil. The content of stearic acid triglycerides is the highest in SRDO (control), 3.6 %, which is 1.2 % higher than this indicator in olive oil, and 0.9 % higher than in SOHO. It should be noted that the highest (89.3 %) oleic acid content is demonstrated by SOHO, compared to SRDO (control), by 63.8 %, and olive oil, by 18.5 %. SRDO (control) has a relatively higher content of polyunsaturated linoleic acid – by 60.6 % compared to SOHO, and by 56.6 % compared to olive oil.

According to experimental research, SOHO has a ratio of linoleic and oleic acids of 0.14:1. Our analytical studies indicate that SOHO and olive oil are very similar in fat content, and have high nutritional and physiological value.

During analytical research, it was established that a characteristic feature of the new concept of culinary production is the widespread use of olive oil containing about 84 % monounsaturated oleic acid. However, the use of this type of raw materials, both in the food for people and in the production of culinary products, is complicated by the fact that olives are costly raw materials. Innovative approaches to the production of fats make it possible to obtain vegetable oils with optimal fat-acid content and with the predefined physicochemical properties when using various methods and technologies. Predictably, SOHO is characterized by high resistance to oxidation processes, both during storage and under the influence of heat treatment. Therefore, scientific interests focused on the use of SOHO as the base to produce a fat-based semi-finished product.

To prepare model samples of oleogels, we used bees wax 8108 (manufactured by KahlWax (Kahl GmbH & Co., Trittau, Germany). Beeswax is white solid granules with a faint odor, with a melting point of 62...65 °C; it has the status of GRAS. Beeswax (BW) is also recognized as the food additive E 901, used worldwide, it is an organic wax produced by bees from the genus *Apis mellifera L.* It consists of 70...71 % of general complex esters, 1...1.5 % of free alcohols, 9...11 % of free acids, and 12...15 % of hydrocarbons.

The monoglyceride E 471 (MG) is a white, odorless and tasteless, micro-dispersed powder containing at least 90 % of hydrogenated palm oil monoglyceride; it has a melting point of 64...68 °C. Monoglycerides were added to improve the structure of the semi-finished product, as it regulates fat crystals, increases the stability of the "water-in-oil" system, and prevents the separation of the "oil-water" emulsion. In addition, monoglyceride improves the properties of mixing and whipping, improves the texture, and prolongs the shelf life of the finished product. Monoglyceride is an emulsifier, so it makes it possible to reduce the size of fat balls and ensures their uniform distribution, which accelerates and facilitates the preparation of a homogeneous dough or emulsion in the subsequent preparation of sponge-cake based on a fat-based semi-finished product. The interaction of emulsifiers with flour proteins strengthens gluten, which in the production of flour confectionery leads to an increase in specific volume, improved porosity, the structure of the crust, slowing down staleness.

Advantages of using monoglyceride are:

– obtaining finely dispersed and stable emulsions [38];

– uniform distribution of components in the product [39];

– small, uniform pores in finished products [40];

– prolonging the terms of freshness of finished products [41].

Table 2

Fat-acid composition of oils

Oil name	Fatty acid content, %							
	palmitic C16:0	palmitoleic C16:1	stearic C18:0	oleic C18:1	linolenic C18:2	linolenic C18:3	eucosenic C20:0	behenic C22:0
SRDO	6.83±0.34	0.140±0.005	3.68±0.18	25.44±1.27	62.61±3.13	0.190±0.005	0.150±0.005	0.70±0.02
Olive oil [39]	11.53±0.57	0.76±0.02	2.63±0.13	70.77±3.53	9.98±0.50	0.76±0.02	>0.01	0.160±0.005
SOHO	3.93±0.11	0.180±0.005	2.82±0.08	89.3±2.7	2.00±0.06	0.30±0.009	0.50±0.01	0.70±0.02

Based on the model samples of oleogels, sponge-cake batter was prepared, a margarine-based sponge-cake batter was chosen as control, which includes hydrogenated vegetable oils ,79 %, milk, salt, sugar, emulsifiers, flavors.

In order to develop a fat-based semi-finished product with the predefined technological and structural and mechanical properties close to margarine, the formulation fat mixture was prepared at different concentrations of organogelators (Table 3).

Table 3

Matrix of model samples of fat-based semi-finished product

Sample name	Content, %		
	SOHO	monoglyceride	beeswax
SOHO:MG:BW – 1	90	7	3
SOHO:MG:BW – 2	90	3	7
SOHO:MG:BW – 3	90	–	10
SOHO:MG:BW – 4	90	10	–
SOHO:MG:BW – 5	90	5	5

For the preparation of experimental samples of the fat semi-finished product (oleogel), we built on the research of predecessors [38–41] and chose the concentrations of organogelators (BW/MG) in the amount of 0...10 %. At the first stage of the preparation of the fat-based semi-finished product, the required amount of BW and MG (Table 3) was measured in glasses, after which the glasses were heated in a water bath to a temperature of 90 °C. During the isothermal process, after complete melting of organogelators, SOHO was added to them, after which their contents were mixed for 5 minutes. Then the finished mixture was poured into molds, cooled, and directed to structure formation for 12 hours, after which the finished fat semi-finished product (oleogel) was sent for research. In order to determine the expiration date, the finished fat-based semi-finished product was stored at room temperature (20 °C) or in the refrigerator (4 °C) and studied for 12 months. The experimental samples of the fat-based semi-finished product (oleogel) based on beeswax and monoglyceride are shown in Fig. 1.

In order to determine the feasibility of using the semi-finished fat-based product (oleogel) in the production of sponge-cake batter products, we investigated the physicochemical and structural and mechanical properties of model samples of the fat-based semi-finished product and compared their characteristics with margarine.

The comparative characteristics of the physical and chemical indicators of the samples of the fat-based semi-finished product and margarine (control) are given in Table 4.

Compared to margarine, the color values (*L*) of all samples of the fat-based semi-finished product were much lower since SOHO is natural and untreated oil and contains some color pigments. In addition, because margarines are emulsion products, their color is usually whiter than that of oil. It should be noted that the *L* values of samples of the fat-based semi-finished product increase with an increase in the level of BW due to the natural color of wax.

a *b*

Fig. 1. Experimental samples of fat-based semi-finished product (oleogel) based on beeswax and monoglyceride: *a* — before solidification; *b* — after solidification

Table 4

Comparative characteristics of the physicochemical parameters of fat-based semi-finished product and margarine (control)

Sample title	Color (*L*)	Fat-retaining capacity, % (FRC)	Duration of crystal formation (60^2 s)	The content of the solid fraction 20 °C (%)	The content of the solid fraction 35 °C (%)
No. 1	42.41	97.72	8.00	8.71	4.69
No. 2	44.95	95.34	9.25	8.52	4.23
No. 3	54.46	93.41	7.50	8.45	4.17
No. 4	35.49	99.87	7.50	9.38	4.75
No. 5	43.09	96.64	8.50	8.64	4.37
Margarine (control)	87.23	–	–	12.15	–

It should be noted that the color, if necessary, can be adjusted by adding soluble food pigments to the formulation mixture.

Since the fat-based semi-finished products, according to the innovative plan, should be characterized by certain properties, we investigated its structural and mechanical properties (fat-retaining capacity (FRC), the formation time of crystals, and the content of solid fraction).

In order to determine the ability of organogelators to retain oil, and, as a result of the stability of the fat-based semi-finished product, we determined the fat-retaining capacity of the fat-based semi-finished product samples. It was established that the fat-retaining capacity depends on the level of added organogelators, respectively. In general, the results of the fat-retaining capacity were better in samples that contained MG in the amount of 5...10 %.

The duration of crystallization (DC) also characterizes the ability of organogelator molecules to gel formation [15, 26–30]. The experimental data in Table 4 indicate that the addition of organogelators in the amount of 3...10 % to SOHO ensures the formation of the gel structure in all samples within 7.5...9.25 mins. It should also be noted that if the concentration of MG in samples increases, the duration of crystallization decreases, respectively. There were no significant differences in the duration of crystallization in the samples of SOHO:BW:MG at the ratio of 90:5:5, respectively.

The content of a solid fraction of fat is a very important criterion because it determines the technological purpose of fat, especially it is an important indicator of quality in the production of sponge-cake batter products. It is noted that the content of the solid fraction of fat in all samples depended on the ratio in their composition of BW and MG. That is, with an increase in the content of MG, the content of a solid fraction of fat in the predefined temperature range of 20 °C and 35 °C increased. Note that with an increase in temperature, this indicator decreased to the minimum values in all samples under study. The literary data [30–30, 41] confirm this phenomenon, and indicate that in the predefined temperature interval, some of the organogelators are in a liquid state.

In order to reveal a wider range of possibilities for the use of the new fat-based semi-finished product, the crystallization and melting temperatures of experimental samples were determined (Table 5).

Samples of the fat-based semi-finished product (Table 5) have peak melting point values. They vary in a wide range of 12.30....51.80 °C while the peak melting point for margarine is 47.10 °C (even though the manufacturer of margarine noted its melting point within 64...68 °C). The experimental data demonstrate that in terms of the melting and crystallization temperatures, similar to control are samples 1, 2, and 5 with the addition of beeswax and monoglyceride wax in the amount of 3...7 %.

Table 5

Comparative characteristics of the thermal properties of the fat-based semi-finished product and margarine (control)

Sample name	Crystallization			Melting		
	initial crystallization temperature (°C)	peak crystallization temperature (°C)	enthalpy of crystallization, ΔH_c ($J \cdot g^{-1}$)	initial melting temperature (°C)	peak melting temperature (°C)	enthalpy of melting ΔH_m ($J \cdot g^{-1}$)
Sunflower oil of high oleic type	−13.50	−17.20	−6.15	−12.65	−3.95	71.35
Beeswax	61.90	59.05	−167.80	52.80	60.30	183.70
Monoglyceride	11.15	10.14	−23.30	10.65	13.20	24.20
(Fr2)a	63.85	61.15	−105.71	61.75	65.83	103.95
Margarine	19.45	16.90	−2.90	35.35	47.10	94.20
No. 1	12.75	11.15	−1.30	10.85	12.70	1.25
(Fr2)	45.20	41.95	−5.45	38.30	49.70	4.90
No. 2	12.65	11.10	−0.45	10.70	12.30	0.50
(Fr2)	42.80	37.75	−1.50	35.10	46.00	1.80
No. 3	36.95	34.85	−1.75	31.05	39.60	1.45
No. 4	12.40	10.85	−2.05	10.75	12.55	2.10
(Fr2)	49.00	45.80	−7.65	43.35	51.80	6.50
No. 5	12.55	11.15	−1.20	10.75	12.45	0.95
(Fr2)	44.15	39.80	−6.35	36.80	45.80	1.40

Note: Fr2 – fraction II

We have investigated such indicators of the fat-based semi-finished products as hardness, adhesion, resistance to oxidation processes, organoleptic indicators. For further research, experimental samples were stored at temperatures of 5 °C and 20 °C for 90 days. The experimental study into the hardness of the fat-based semi-finished product is illustrated in Fig. 2, 3.

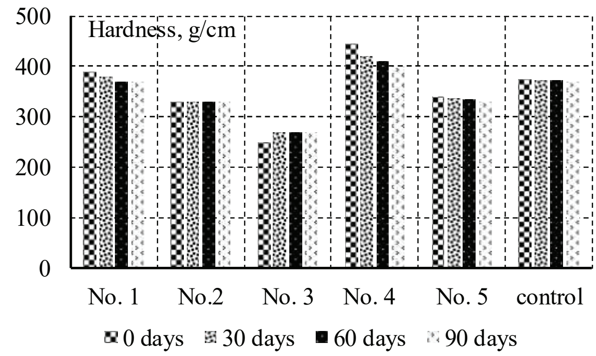

Fig. 2. Change in the hardness of the fat-based semi-finished product over time (0, 30, 60, 90 days) at a temperature of 5 °C

Experimentally, it was established that the addition of organogelators to the samples in the amount of 3...10 % provides the required hardness values of all samples. For samples stored at temperatures of 5 °C and 20 °C, the initial hardness values of the fat-based semi-finished products increased with an increase in the content of monoglyceride in the samples. However, it should be noted that during storage for 90 days, the hardness values in these samples (1, 4) were gradually reduced compared to samples (2, 3, 5) that contained a greater amount of beeswax. This can be explained by the fact that saturated monoglycerides were used as an organogelator, which may vary during storage depending on the temperature. Consequently, the hardness values of the fat-based semi-finished products during storage at a temperature of 5 °C were as follows: 1 – 390...370 g/cm, 2 – 330...340 g/cm, 3 – 250...270 g/cm, 4 – 445...400 g/cm, 5 – 340...330 g/ cm, control – 375...370 g/cm, and, at a temperature of 20 °C: 1 – 80...67 g/ cm, 2 – 60...65 g/cm, 3 – 55...60 g/cm, 4 – 120...90 g/cm, 5 – 70...63 g/cm, control – 83...67 g/cm. The experimental data show that the smallest value of hardness is demonstrated by the sample containing only beeswax in the amount of 10 % at a temperature of 20 °C, and the largest – the sample with the addition of only monoglyceride in the amount of 10 % at a temperature of 5 °C. In general, it should be noted that the samples were not critically different from each other. According to the hardness indicator, the closest to control was sample No. 1, containing the sunflower oil of high-oleic type – 90 %, monoglyceride – 7 %, and 3 % of beeswax.

Radically opposite dynamics of changes were observed when measuring the adhesion of the studied samples (Fig. 4, 5).

During storage at a temperature of 5 °C and 20 °C, the values of adhesion indicators in the samples depended in proportion to the content of beeswax. In addition, adhesion values were higher for samples stored in the refrigerator compared to those stored at room temperature. The lowest adhesion values characterized sample No. 4, which contained only monoglyceride in the amount of 10 %, and was stored at a temperature of 20 °C for 90 days; the highest – sample No. 3, with the addition of only beeswax in the amount of 10 %, which was stored at a temperature of 5 °C for 90 days. The values of margarine adhesion ranged from 196 g for the sample stored at a temperature of 20 °C for 90 days to 208 g, for the sample stored at a temperature of 5 °C for 90 days.

In order to study the oxidation processes that can occur in the fat-based semi-finished product, we studied the peroxidation number of samples during 3 months of storage at a temperature of 5 °C and 20 °C (Fig. 6, 7). At the acceptance control for fat, PN should not exceed 1 mmol ½ O/kg.

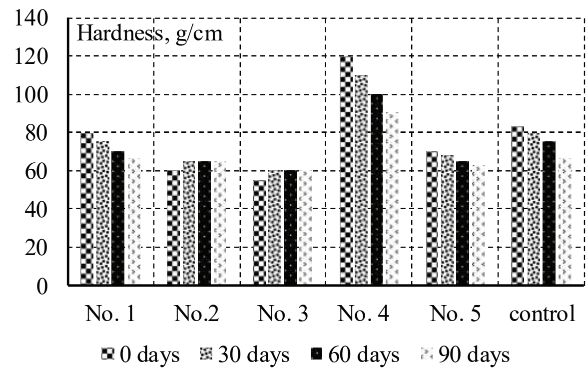

Fig. 3. Change in the hardness of the fat-based semi-finished product over time (0, 30, 60, 90 days) at a temperature of 5 °C

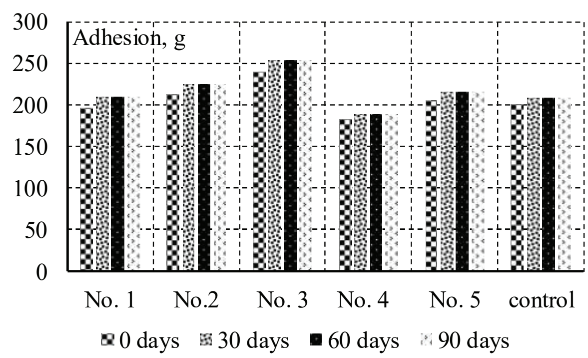

Fig. 4. Change in the fat-based semi-finished product adhesion over time (0, 30, 60, 90 days) at a temperature of 5 °C

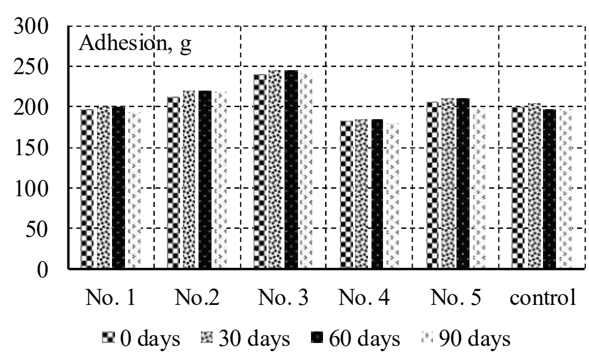

Fig. 5. Change in the fat-based semi-finished product adhesion over time (0, 30, 60, 90 days) at a temperature of 20 °C

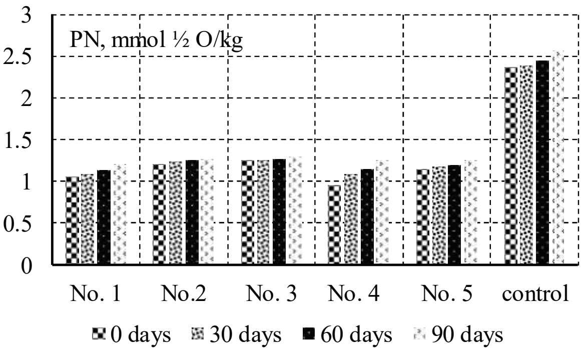

Fig. 6. Change in the peroxide number of the fat-based semi-finished product over time (0, 30, 60, 90 days) at a temperature of 5 °C

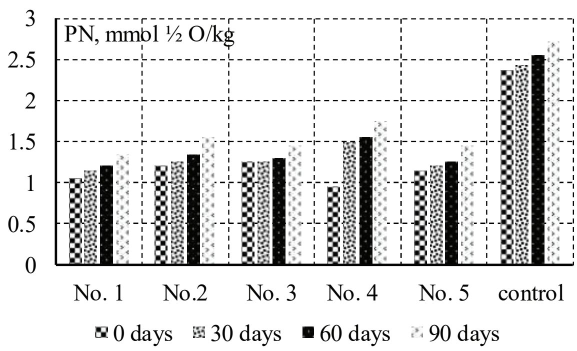

Fig. 7. Change in the peroxide number of the fat-based semi-finished product over time (0, 30, 60, 90 days) at a temperature of 20 °C

5. 2. Investigating the physical-chemical indicators of the model samples of sponge-cake batter containing the fat-based semi-finished product

To prepare the samples of sponge-cake batter, in parallel, in separate vessels, samples of oleogels, egg yolks together with sugar (50 % of the total) and egg whites were whipped to a temperature of 30 °C. After that, 50 % of sugar was added to the whipped egg whites at the end of whipping. Next, the whipped yolks and whites were mixed, after which the whipped samples of oleogel or margarine (control) were added gently. At the end, sifted flour was added together with starch and gently mixed for 15...20 sec. We baked the sponge-cake batter products at a temperature of 190...200 °C for (40...45)·60 s. The samples of freshly prepared dough, as well as the baked, chilled, and aged sponge-cake semi-finished products were selected for research.

The recipe composition of model samples of the sponge-cake semi-finished product is given in Table 6.

Replacement of solid (saturated) fats with liquid (unsaturated) in the technology of sponge-cake batter products leads to certain technological problems. First, fats in sponge-cake batter technology should be used in the form of finely dispersed emulsions. This contributes to a better distribution of fat particles in the form of thin films between flour particles, which prevents the swelling of flour colloids. As a result, the bond between the components of the solid phase of the dough is weakened, the dough acquires plastic properties. The smaller the thickness of the fat films, the crumblier the finished products. In addition, unsaturated fats emulsify poorly, so emulsions formed on their base, when compared to emulsions on solid (saturated) fats, are characterized by less resistance. This also causes a deterioration in the quality of baked products. Second, unsaturated fats are easily separated from the dough during baking and poorly retain the bubbles of gas released during the disintegration of leavening agents. As a result, porosity decreases while the organoleptic properties of finished products deteriorate. Third, unsaturated fats are poorly maintained by finished products during storage. As a result, there is a migration of fat into packaging materials and deterioration of presentation and taste characteristics of products [23].

Table 6

Recipe composition of the model samples of sponge-cake semi-finished product

Raw material type	Sample using margarine (control)		Sample using a fat-based semi-finished product (1–5)	
	The amount of raw materials per 1 ton of semi-finished product, kg		The amount of raw materials per 1 ton of semi-finished product, kg	
	actual	dry matter	actual	dry matter
Wheat flour h/g	265.04	226.61	265.04	226.61
Potato starch	65.44	52.36	65.44	52.36
Margarine	54.53	45.80	–	–
Fat-based semi-finished product	–	–	54.53	45.80
White sugar	327.20	326.71	327.20	326.71
Eggs of poultry	545.33	147.24	545.33	147.24
Flavoring agent	3.28	0.00	3.28	0.00
Total	1.260.82	798.72	1.260.82	798.72
Yield	1.000.00	750.00	1.000.00	750.00

Therefore, the next stage of our research was to determine the effect of the developed fat-based semi-finished products (oleogels) on the quality of sponge-cake batter and finished products. For this purpose, the physicochemical and structural-mechanical properties of the samples of sponge-cake batter and baked semi-finished products were studied (Table 5).

An important technological indicator of sponge-cake batter, which predetermines the stability of the foam-type system to the action of loads, is its viscosity. This rheological characteristic is closely related to the internal structure of sponge-cake batter. High structural viscosity determines the mechanical strength of the dough, that is, it creates an elastic frame, which gives the system certain physicochemical properties of the solid. The stability of the sponge-cake batter is mainly due to the viscosity of the original mixture, which, subject to a fixed cooking temperature (20...25 °C), depends on the amount of solids, the presence of moisture-binding formulation components, the concentration of fat, sugar, etc.

Therefore, it was considered appropriate to determine the effective viscosity of the dough for sponge cake at various shear deformations depending on the type of fat-based semi-finished product. According to the acquired data on the curves of the dough flow for sponge cake containing the developed fat-based semi-finished products, we established, in all samples, a decrease in viscosity with an increase in the shear rate, which is consistent with known scientific works [12, 23] and allows us to attribute this polydisperse system to non-Newton liquids.

According to the reported results of the dependence of the effective viscosity of sponge-cake batter on the shear rate when using the fat-based semi-finished product (Fig. 8), a general trend has been established, which is a slight fluctuation in viscosity for all samples of sponge-cake batter when margarine is completely replaced with the samples of fat-based semi-finished products. Thus, under the studied shear deformations from 0.167 to 24.3 s^{-1}, the viscosity of the experimental batter samples decreases as follows: 1 – 50.0...1.7 Pa·s; 2 – 51.1...1.8 Pa·s; 3 – 51.7...1.9 Pa·s; 4 – 49.0 ...1.0 Pa·s; 5 – 50.5...1.6 Pa·s; control – 49.6...1.4 Pa·s. That is, the largest viscosity is demonstrated by an indestructible structure, which, with increasing stress, begins to collapse.

Patterns of behavior of shear stress (Fig. 9) as regards the experimental batter samples indicate an increase in this indicator in samples No. 1, 2, 3, 5 by 5.3...26.3 %, and a decrease in sample No. 4, by 5.2 %, relative to control at shear speeds from 0.17 to 72.9 s^{-1}.

That is, with the same shear strains, the destruction of the structure of the batter for sponge cake comes under a greater mechanical effect. This explains the increase in the resistance of sponge-cake batter to the effects of destructive loads.

Fig. 10 shows the experimental samples of sponge-cake batter products when using the fat-based semi-finished product.

Table 7

Physical properties of the samples of sponge-cake batter products prepared by using the fat-based semi-finished products and margarine (control), $p^{*}<0.05$

Sample title	Sample mass, g	Moisture content, W (%)	Specific volume, $V_{specific}$ (m^3/kg)	Total porosity, %	Shrinkage, %	Compressibility, device units
No. 1	25.05	22.11	428	83	18.4	131
No. 2	24.99	21.51	386	79	19.4	125
No. 3	24.87	21.18	354	73	19.1	122
No. 4	25.0	21.44	350	72	18.6	120
No. 5	25.15	22.49	420	80	19.0	130
Control	25.31	20.72	358	75	19.5	123

*Note: * – the least likely difference, the effects are reliable at the 5 percent level*

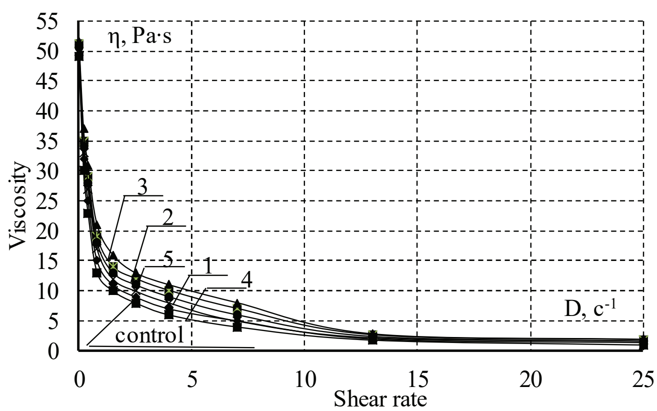

Fig. 8. Dependence of the effective viscosity of sponge-cake batter on shear rate when using the fat-based semi-finished product

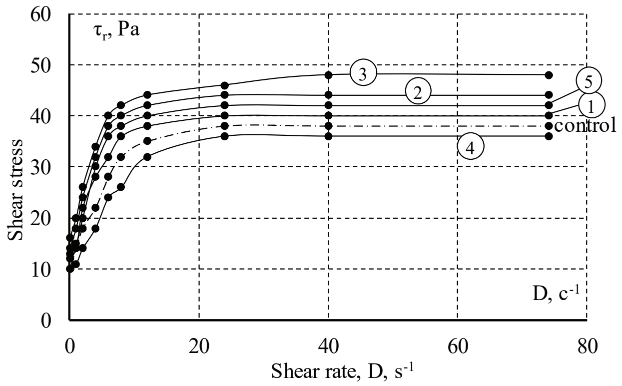

Fig. 9. Dependence of shear stress on the shear rate for sponge-cake batter when using the fat-based semi-finished product

Fig. 10. Experimental samples of sponge-cake batter products: No. 1; No. 2; No. 3; No. 4; No. 5; control

In order to determine the effect of the fat-based semi-finished product on the structural and mechanical properties of baked products from sponge-cake batter, the dimensional characteristics of the samples were studied. Experimentally, it has been established that there are no significant differences in mass and diameter in all samples. However, it should be noted that samples No. 1, 2, 5 had larger diameter values within 5 %, and height values within 22 % compared to the control, and samples No. 4 and 3.

The mass fraction of moisture in all samples was higher compared to the control sample and ranged within 21.18...22.49 %. Since the samples were prepared while strictly monitoring the specified parameters of the technological process, and the samples had an identical mass before baking, we can conclude that the ability to retain moisture in products directly depends on the fat-based semi-finished product used.

The positive effect of the developed fat-based semi-finished products on the quality of finished products is also confirmed by studying the porosity, specific volume, and compression ability. The porosity of the sponge cake, taking into consideration its structure (pore size, their uniformity), characterizes its important property – greater or less digestibility, which cannot be ignored when assessing the quality of the texture characteristics of the sponge cake. Its assimilation is associated with it since the porous product is better impregnated with the juices of the gastrointestinal tract, and is digested well [2, 15, 23–31]. The high taste characteristics of the products are also provided by porous crumb. Products with a porous structure are quickly and well baked. The porous structure of sponge cake crumb and the height of the products were also determined by its specific volume. The high moisture-holding ability of the developed samples of the fat-based semi-finished product makes it possible to predict a decrease in shrinkage and an increase in the yield of finished products [31, 32].

Our studies have shown that the use of the developed samples of fat-based semi-finished products increases porosity in sponge cake samples No. 1, 2, and 5 by ≥10.7, compared to control.

During the study, organoleptic indicators of the quality of finished products were evaluated by the sensory method. The highest rating was given to the sample of sponge cake No. 1 due to the pronounced balanced taste and well-loosening and elastic crumb, which is due to the use of the fat-based semi-finished product. The lowest level of quality in terms of the state of the crumb characterized the control, as well as samples No. 3 and 4 (4.4 points). This is due to the less developed and uniform porosity and loose characteristics of the crumb.

The quality of sponge cakes when using the fat-based semi-finished products was supplemented by studying the degree of fat migration into packaging materials (Fig. 11).

It was established that the release of fat is more intensive on day 7 of storage of the finished products. After 10 days of storage, the sponge cakes made on the fat-based semi-finished product (samples No. 1, 2, 4, 5) release 2.0 times less fat than that from the control sample (Fig. 11). However, it should be noted that in sample No. 3, the degree of fat migration was the highest, and amounted to 0.42 %. Such an effect of the fat-based semi-finished products is due to the peculiarities of the composition of their monoglycerides, which exhibit surface-active properties.

Therefore, the feasibility of using SOHO has been experimentally established as a base for the fat-based semi-finished product, as well as a rational percentage of organogellators (monoglyceride, 7 %; beeswax, 3 %), which could provide obtaining a fat-based semi-finished product for its intended purpose. Based on the conclusion, we have developed a draft formulation for a fat-based semi-finished product for sponge-cake batter (Table 8).

Table 8

Proposal for the recipe composition of the fat-based semi-finished product

Raw material type	Raw material consumption per 100 g of finished fat-based semi-finished product
Sunflower oil of high oleic type	90
Monoglyceride (saturated)	7
Beeswax	3
Yield of fat-based semi-finished product	100

The developed fat-based semi-finished product must be manufactured in accordance with the acting technological regulations DSP 4.4.4 – 90. In terms of the organoleptic and physicochemical indicators, the fat-based semi-finished product containing organogelators must meet the requirements specified in Table 9.

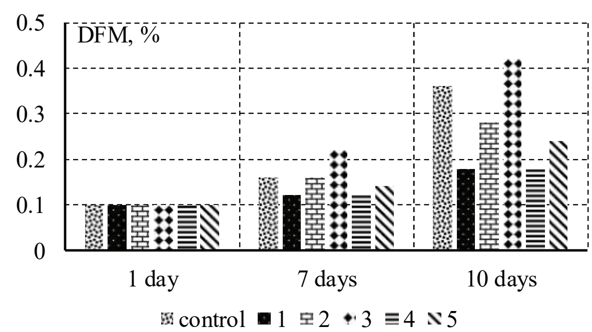

Fig. 11. Degree of fat migration (DFM) from the studied sponge cake samples after 1, 7, and 10 days of storage

Table 9

Organoleptic and physicochemical parameters of the fat-based semi-finished product

Indicator	Characteristic
Smell and taste	Pure taste, typical of fat, without foreign taste and odor
Color	From light yellow to yellow
Consistency	Homogeneous, solid, plastic
Mass fraction of moisture, %, not more than	0.30
Mass fraction of fat,%, not less than	99.70
Acid number, mg KOH/g, not more than	0.4
Melting point, °C	From 10 to 38
Crystallization temperature, °C	From 12 to 45
Peroxide number, ½ O mmol/kg	2.0
Mass fraction of solid triacylglycerols at a temperature of 20 °C, %	8.71
Hardness, at a temperature of 5 °C, g/cm	370...390
Hardness, at a temperature of 20 °C, g/cm	67...80

Our set of the theoretical and experimental studies have made it possible to devise recommendations on the use of the developed fat-based semi-finished product in the technology of sponge-cake batter products.

5. 3. Development of the recipe composition and the technological scheme for making sponge-cake batter products based on the fat-based semi-finished product

The recipe for sponge-cake batter products based on the fat-based semi-finished product (oleogel) is given in Table 10.

To prepare the fat-based semi-finished product, the required amount of beeswax (3 %) and monoglyceride (7 %) is measured into a thermally-resistant capacity, after which its contents are heated in a water bath to a temperature of 90 °C. During the isothermal process, after complete melting of organogelators, high oleic sunflower oil (90 %) is added, after which the resulting mixture is agitated for 5 minutes. After that, the finished mixture is poured into molds, cooled, and sent to the structure formation within 12 hours. The finished fat-based semi-finished product containing monoglyceride and beeswax is used to make sponge-cake batter products.

To prepare the sponge-cake batter, in parallel, separately in three vessels, the fat-based semi-finished product heated to a temperature of 30...36 °C is whipped, with egg yolks together with sugar (50 % of the total), as well as egg whites. Egg whites are whipped to an increase in volume by 5–6 times. 50 % of sugar is added to the whipped egg whites at the end of whipping. Next, we combine the whipped yolks and whites, after which, by gently stirring, we add the whipped fat-based semi-finished product. At the end, we add the sifted flour together with starch and stir gently. The batter is kneaded carefully but quickly (for 15...20 sec.). The finished batter is carefully transferred to oiled baking molds and baked according to the technological parameters t=(190...200) °C, τ=(40...45)·60 s, or t=(170...175) °C, τ=(65...70)·60 s, W=25±3 %. Next, the baked sponge-cake batter products are cooled at a temperature of t=20...25 °C for τ=(25...30)·60 s, then aged at a temperature of t=15...20 °C for τ=(8...10)·602 s and sent for selling.

The technological scheme of the product from sponge-cake batter based on the fat-based semi-finished product is shown in Fig. 12.

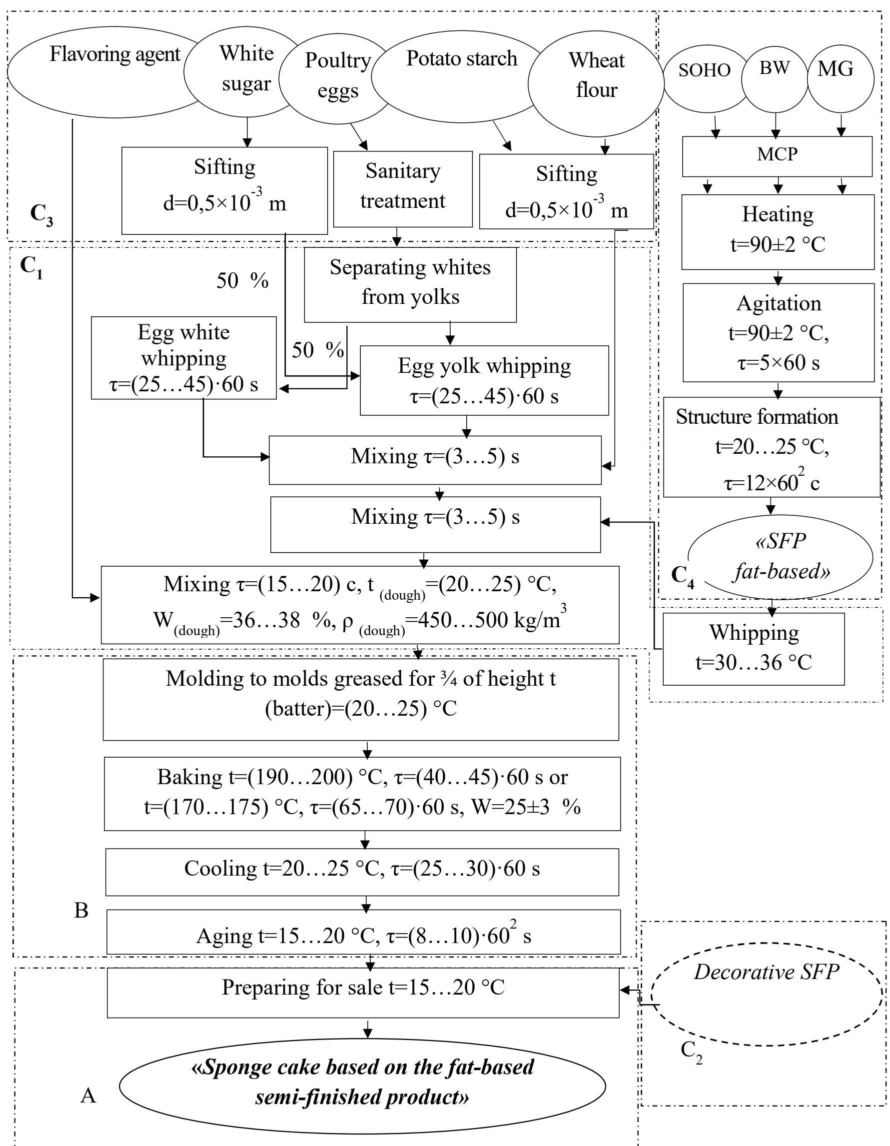

Fig. 12. Technological scheme of the product made from sponge-cake batter "Sponge cake based on the fat-based semi-finished product"

Table 10

Recipe composition of sponge-cake batter products based on the fat-based semi-finished product

Raw material type	Mass fraction of dry matter, %	Calculation of raw materials per 1 kg of semi-finished product, g	
		actual	dry matter
Wheat flour h/g	85.5	265.04	226.61
Potato starch	20.0	65.44	52.36
Fat-based semi-finished product (Table 8)	84.0	54.53	45.80
White crystalline sugar	99.85	327.20	326.71
Eggs of poultry	27.0	545.33	147.24
Flavorant	0.00	3.28	0.00
Total raw materials on semi-finished product (SFP)	–	1,260.82	798.72
Yield of finished products	–	1,000.00	750.00

The peculiarity of the model in question is its multifunctionality, that is, it can be implemented both in specialized food production shops and at restaurant enterprises.

6. Discussion of results of studying the development of the fat-based semi-finished product for sponge-cake batter products

The results of our research are several systemic results for making sponge cake batter when using a fat-based semi-finished product.

The technology of butter sponge-cake batter products, which are characterized by large pores, specific volume, minimum percentage of shrinkage and long shelf life, is offered as the object of realization.

It can be predicted that the complete replacement of margarine with the fat-based semi-finished product could completely replace the role of the fat component for sponge cake batter.

The formation of a plastic texture of the fat-based semi-finished product with high mechanical strength of the foam will be reached by whipping up a reversible emulsion, which is a high oleic sunflower oil. To provide the emulsion with foaming ability, the monoglyceride emulsifier will be used. Monoglyceride will reduce interphase surface tension. To ensure stabilization of the emulsion, beeswax will be used.

The melting range for monoglyceride samples is measured by two different melting points at 13.20 °C and 65.83 °C. This is due to the fact that monoglyceride is by nature a two-component system that has a high and low melting point of fractions. A significant difference between the two values of the melting point may indicate that there is a fraction in the saturated monoglyceride that has a low melting point since the melting point curve gives two separate enthalpic curves. Therefore, in all samples of the fat-based semi-finished products that contained monoglyceride as an organogelator, two fractions of melting were found. Although when comparing the fat-based semi-finished product with margarine, it should be remembered that margarine is an emulsion product that has an aqueous phase and several additional ingredients, which ensure its plasticity and taste. The studied fat-based semi-finished product are water-free systems, which are characterized by structural and mechanical properties similar to margarine (plasticity and melting temperature). It is worth noting that the low resistance to melting in margarine at room temperature is an undesirable factor from a technological point of view. The reason for this phenomenon may be the insufficient size of the crystals or their nature.

Analyzing the obtained data from experimental studies of the structural and mechanical properties of the fat-based semi-finished product, it was established that the developed samples are very similar in properties to margarine. The sample with the addition of 7 % of monoglyceride and 3 % of beeswax is similar to margarine while other samples are characterized by insignificant deviations, so additional studies can be considered as components of the food system.

Our experimental data (Fig. 6, 7) indicate that the PN of all the samples studied ranges within 0.95...1.25 mmol ½ O/kg, which indicates a moderate amount of hydroperoxides in the samples. Among all samples of the fat-based semi-finished product, the lowest value of the peroxide number (1.75 mmol ½ O/kg) characterized sample No. 4, which contained 10 % of monoglyceride and was stored at a temperature of 20 °C for 90 days. At the same time, the values of margarine PN were 2.36 mmol ½ O/kg at the beginning of storage at a temperature of 5 °C and 2.76 mmol ½ O/kg for the sample stored for 90 days at a temperature of 20 °C. In general, it should be noted that the PN slowly, gradually increased during storage in all samples, regardless of storage conditions. However, the obtained PN values did not exceed the maximum permissible level of 3 mmol ½ O/kg, which indicates their resistance to oxidation processes. Since no antioxidants were added to the samples, the result of the resistance of the fat-based semi-finished product samples to oxidation may be natural antioxidants (tocopherols) contained in SOHO, which do not collapse during the formation of the fat-based semi-finished product.

Thus, taking into consideration the results of our experimental studies such as the content of solid fat fraction, melting point, enthalpy, PN, hardness, adhesion, and crystalline structure, it becomes possible to use the developed samples of the fat-based semi-finished products in the composition of sponge-cake batter products.

The rheograms of sponge-cake batter testify (Fig. 8) to that it is a structured dispersed system with abnormal viscosity. When the speed gradient increases, the viscosity of the sponge-cake batter first decreases sharply, and then the destruction of the structure slows down, and the effective viscosity decreases more slowly, approaching a constant value at certain values of the speed gradient. Increased shear rate leads to disruption of bonding forces between particles and weakening of the structure. Reducing the viscosity of the batter with an increase in shear rate is explained by the fact that in a stationary environment, particles move erratically. And under the influence of the increasing shear rate, particle acceleration occurs in the direction of the current and a decrease in the interaction between particles. At low shear rates, the structure is characterized by the destruction and restoration of individual bonds, while the batter has the greatest viscosity. With an increase in the shear rate, the destruction of the structure begins to prevail over recovery, the viscosity decreases sharply, at higher speeds the batter has the slightest viscosity.

It was experimentally established that as a result of replacing margarine with fat-based semi-finished products, the viscosity of the batter increases, compared to control, within 5 %, and the shear stress value rises within 5.3...26.3 %. It should be noted that these deviations do not complicate the process of mixing, the batter is well molded, its stability does not decrease. As a result, finished products made of sponge-cake batter are of good quality, as evidenced by the visualization of the baked samples of sponge-cake batter (Fig. 10), as well as their physicochemical and structural-mechanical indicators (Table 7).

Our data on the structural and mechanical properties of batter samples (Table 7) can be explained by the positive effect of used fat-based semi-finished products on the foaming ability of the whipped egg mass, which, in turn, depends on surface tension. The use of fat-based semi-finished product No. 1, 2, and 5 in the production of sponge cake increases the specific volume by 19.5 %. This may be due to an increase in the humidity of the samples containing the developed fat-based semi-finished products, which provide an opportunity to increase the yield of finished products and reduce water activity due to their high water absorption capacity. It should be noted that the percentage of formulation components SOHO:MG:BW, 90:7:3, in the developed fat-based semi-finished product No. 1 makes it possible to obtain a finished product from sponge-cake batter, characterized by the highest values of specific volume and porosity. The change in the compression of the crumb of the new sponge cakes, compared to the control, changes within the margin of error but its changes are tracked in combination with porosity. The decrease in the shrinkage of sponge cakes may be due to the ability of the fat-based semi-finished products to reduce the activity of water and keep water molecules around it, and, in the same way, to slow down the process of moisture release in the batter during baking. The use of the developed fat-based semi-finished products makes it possible to increase the yield of finished products (shrinkage decreases from 19.5 % – in the control sample, to 18.4 % – in sample No. 1).

The advantage of our technology is the possibility of complete replacement of butter or margarine in the butter sponge cake with a fat-based semi-finished product; the result being the products without trans fats, low in saturated fats, and high in mono- and/or polyunsaturated fatty acids. In addition, the introduction of a given technology would reduce the cost of finished products.

Thus, the properties of the fat-based semi-finished product as a formulation component of the butter sponge cake are determined by the following indicators:

– its functional and technological potential (due to the content of high-protein oil) and its ability to implement it in the technological process of butter sponge cake production;

– the colloidal, physical condition, food system texture, and wide range of hardness since the fat-based semi-finished product can be a functionally active component in traditional food technologies (production of shortbread, puff, etc.) only under certain conditions.

It should be noted that the range of our research focused on the development of a fat-based semi-finished product for sponge-cake batter products. Therefore, recommendations for the use of the developed semi-finished product in other confectionery products are restrictive in nature and require additional experimental research.

The disadvantages are the lack of studies into the microbiological and toxicological indicators of the safety of the fat-based semi-finished product for sponge-cake batter products and measures on the critical point hazard analysis system (HACCP) to make these products.

Taking into consideration the limitations of our work, a plan for further experimental research has been devised, which involves the following:

– investigate the use of the fat-based semi-finished product in the technology of flour and confectionery products from puff, custard, sugar, and other types of dough;

– examine the safety indicators and implementation of HACCP system for making products using the fat-based semi-finished product.

7. Conclusions

1. The technological parameters for making fat-based semi-finished products for sponge-cake batter products have been substantiated. During the experiment, we studied the physicochemical indicators of high oleic sunflower oil and compared them with sunflower deodorized oil. It is determined that the experimental oil of the high-oleic type, in terms of the functional and technological properties, is similar to olive oil. Summarizing experimental data, a fat-based semi-finished product has been devised, based on the high-oleic sunflower oil with the addition of a regulator of the consistency, beeswax and monoglycer ide.

The technological process of obtaining a fat-based semi-finished product involved the emulsifying of sunflower oil with beeswax and monoglyceride as a surfactant. During sensory analysis of the fat-based semi-finished product, it was determined that the semi-finished product has a structured gel-like state, which was later indicated as “oleogel”. According to the physical and chemical indicators, the fat-based semi-finished product had more advantages than margarine. Thus, the fat-retaining capacity of the fat-based semi-finished product was 99.87 %, its crystallization took place over $7.50 \cdot 60^2$ s, etc. To ensure the safety of the technological process of making sponge-cake products, as well as its quality, the storage conditions of the fat-based semi-finished product have been studied. It is determined that with a content of 10 % of monoglyceride in the composition of the fat-based semi-finished product, the peroxide number is 1.75 mmol ½ O/kg, whereby the semi-finished product can be stored for 90 days at a temperature of 20 °C

2. Based on experimental data, the physicochemical indicators of model samples from sponge-cake batter containing the fat-based semi-finished product were studied. To develop model samples, a recipe for a traditional butter sponge cake was chosen, with a complete replacement of margarine (or butter with a fat content of at least 72.0 %) with the fat-based semi-finished product. The structural and mechanical indicators of sponge-cake batter with the use of the fat-based semi-finished product were studied. It is determined that the fat-based semi-finished product (SOHO:MG:BW, 90:7:3) increases the viscosity of the batter by 5 % than the traditional margarine dough. According to the physicochemical parameters of the baked sponge cake samples, it was determined that at the content of the fat-based semi-finished product (SOHO:MG:BW, 90:7:3), the samples have a homogeneous porosity which is 79 %, humidity is 21.5 %, the specific volume of the product is 386 m^3/kg.

These indicators include minor errors in comparison with the control sample of a traditional sponge-cake product.

3. The recipe composition and the technological scheme for making sponge-cake batter products using the fat-based semi-finished products have been scientifically substantiat-

ed. In the formulation, margarine was completely replaced with the fat-based semi-finished product (sunflower oil of the high oleic type – 90.0 %, beeswax – 3.0 %, monoglyceride – 7.0 %).

References

1. Radchenko, A., Iurchenko, S. (2021). Study of elamine and stevioside effect on the viscosity of sponge semi-finished products. Progressive engineering and technology of food production enterprises, catering business and trade, 1 (33), 177–187. Available at: https://elib.hduht.edu.ua/bitstream/123456789/6573/1/15.pdf
2. Kravchenko, M., Piddubnuy, V., Romanovskaya, O. (2017). Structural and mechanical properties of egg sponge dough with flour "Zdorovia". The International Scientific-Practical Journal "Commodities and Markets", 2, 86–96. Available at: http://nbuv.gov.ua/UJRN/tovary_2017_2%281%29__11
3. Mykhailo, K., Olha, R., Tetiana, M. (2021). Rheological properties of biscuits dough with spelt flour. The International Scientific-Practical Journal "Commodities and Markets", 2, 94–102. doi: https://doi.org/10.31617/tr.knute.2021(38)09
4. Vukušić Pavičić, T., Grgić, T., Ivanov, M., Novotni, D., Herceg, Z. (2021). Influence of Flour and Fat Type on Dough Rheology and Technological Characteristics of 3D-Printed Cookies. Foods, 10 (1), 193. doi: https://doi.org/10.3390/foods10010193
5. Iorgacheva, E. G., Makarova, O. V., Kotuzaki, E. N. (2014). Vliyanie nekhlebopekarnyh vidov muki na izmenenie kachestva biskvitnyh polufabrikatov pri hranenii. Nauchnye trudy Odesskoy pischevoy akademii, 1 (46), 112–117. Available at: http://tb.chdu.edu.ua/index.php/2073-8730/article/view/40591
6. Tkachenko, A., Syrokhman, I., Lozova, T., Ofilenko, N., Goryachova, E., Hmelnitska, Y., Shurduk, I. (2019). Development of formulations for sponge cakes made from organic raw materials using the principles of a food products safety management system. Eastern-European Journal of Enterprise Technologies, 1 (11 (97)), 60–70. doi: https://doi.org/10.15587/1729-4061.2019.155775
7. Fil, M. I., Koropetska, T. O. (2018). Innovative approach to the technologies of new biscuit roll. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series "Food Technologies", 20 (85), 81–85. doi: https://doi.org/10.15421/nvlvet8515
8. Chugunova, O. V., Zavorohina, N. V., Mysakov, D. S. (2015). Ispol'zovanie ksantanovoy kamedi v kachestve strukturoobrazovatelya pri proizvodstve biskvitnogo polufabrikata. Konditerskoe proizvodstvo, 2, 14–17.
9. Mysakov, D. S., Chugunova, O. V., Zavorohina, N. V., Pankrat'eva, N. A. (2014). Ispol'zovanie ksantanovoy kamedi v kachestve strukturoobrazovatelya pri proizvodstve biskvitnogo polufabrikata. Novye tekhnologii. Available at: https://cyberleninka.ru/article/n/ispolzovanie-ksantanovoy-kamedi-v-kachestve-strukturoobrazovatelya-pri-proizvodstve-biskvitnogo-polufabrikata
10. Stankov, S., Baeva, M., Petkova, N. (2018). Physical and sensory characteristics of sponge cakes containing an additive of modified fructooligosaccharides. International Food Research Journal, 25 (5), 2099–2103. Available at: http://www.ifrj.upm.edu.my/25%20(05)%202018/(45).pdf
11. Maksyutova, M. A., Leonova, S. A., Nikiforova, T. A. (2018). Usovershenstvovanie retseptury biskvitnogo polufabrikata. Hleboprodukty, 9, 51–54. Available at: https://khlebprod.ru/289-zhurnaly-2018/9-18/3451-usovershenstvovanie-retseptury-biskvitnogo-polufabrikata
12. Adeniyi, P., Obatolu, V. A., Bakare, A. D., Lawal, S. B., Bolaji, A. T., Banjo, O. A. (2017). Fortification of Carbohydrate-rich Foods (Spaghetti and Tapioca Pearls) with Soybean Flour, a Timely and Evergreen Necessity. Journal of Food Security, 5 (2), 43–50. Available at: http://pubs.sciepub.com/jfs/5/2/4/index.html
13. Kakie zhe pischevye dobavki nailuchshe uvelichivayut srok hraneniya muchnyh konditerskih izdeliy (2013). Khlibopekarska i kondyterska promyslovist Ukrainy, 9, 12–13.
14. Pușcaș, A., Mureșan, V., Socaciu, C., Muste, S. (2020). Oleogels in Food: A Review of Current and Potential Applications. Foods, 9 (1), 70. doi: https://doi.org/10.3390/foods9010070
15. Sirbu, A., Arghire, C. (2017). Functional bread: Effect of inulin-type products addition on dough rheology and bread quality. Journal of Cereal Science, 75, 220–227. doi: https://doi.org/10.1016/j.jcs.2017.03.029
16. Ktenioudaki, A., Alvarez-Jubete, L., Smyth, T. J., Kilcawley, K., Rai, D. K., Gallagher, E. (2015). Application of bioprocessing techniques (sourdough fermentation and technological aids) for brewer's spent grain breads. Food Research International, 73, 107–116. doi: https://doi.org/10.1016/j.foodres.2015.03.008
17. Goralchuk, A., Andreeva, S., Dikhtiar, A., Riabets, O., Chekanov, M. (2019). The prospects of trans fats replacement in food products. Prohresyvni tekhnika ta tekhnolohiyi kharchovykh vyrobnytstv restorannoho hospodarstva i torhivli, 2 (30), 7–23. Available at: https://elib.hduht.edu.ua/bitstream/123456789/5052/1/1.pdf
18. Marangoni, A. G. (2012). Organogels: An Alternative Edible Oil-Structuring Method. Journal of the American Oil Chemists' Society, 89 (5), 749–780. doi: https://doi.org/10.1007/s11746-012-2049-3
19. Patel, A. R., Dewettinck, K. (2016). Edible oil structuring: an overview and recent updates. Food & Function, 7 (1), 20–29. doi: https://doi.org/10.1039/c5fo01006c
20. Patel, A. R. (Ed.) (2018). Edible Oil Structuring: Concepts, Methods and Applications. Royal Society of Chemistry. doi: https://doi.org/10.1039/9781788010184
21. Yılmaz, E., Öğütcü, M. (2014). Oleogels of virgin olive oil with carnauba wax and monoglyceride as spreadable products. Grasas y Aceites, 65 (3), e040. doi: https://doi.org/10.3989/gya.0349141

22. Gómez-Estaca, J., Pintado, T., Jiménez-Colmenero, F., Cofrades, S. (2020). The effect of household storage and cooking practices on quality attributes of pork burgers formulated with PUFA- and curcumin-loaded oleogels as healthy fat substitutes. LWT, 119, 108909. doi: https://doi.org/10.1016/j.lwt.2019.108909
23. O'Sullivan, C. M., Barbut, S., Marangoni, A. G. (2016). Edible oleogels for the oral delivery of lipid soluble molecules: Composition and structural design considerations. Trends in Food Science & Technology, 57, 59–73. doi: https://doi.org/10.1016/j.tifs.2016.08.018
24. Patel, A. R. (2018). Shellac-Based Oleogels. Edible Oleogels, 173–192. doi: https://doi.org/10.1016/b978-0-12-814270-7.00007-1
25. Öğütcü, M., Arifoğlu, N., Yılmaz, E. (2015). Preparation and Characterization of Virgin Olive Oil-Beeswax Oleogel Emulsion Products. Journal of the American Oil Chemists' Society, 92 (4), 459–471. doi: https://doi.org/10.1007/s11746-015-2615-6
26. Da Pieve, S., Calligaris, S., Panozzo, A., Arrighetti, G., Nicoli, M. C. (2011). Effect of monoglyceride organogel structure on cod liver oil stability. Food Research International, 44 (9), 2978–2983. doi: https://doi.org/10.1016/j.foodres.2011.07.011
27. Lupi, F. R., Gabriele, D., Greco, V., Baldino, N., Seta, L., de Cindio, B. (2013). A rheological characterisation of an olive oil/fatty alcohols organogel. Food Research International, 51 (2), 510–517. doi: https://doi.org/10.1016/j.foodres.2013.01.013
28. Hwang, H.-S., Kim, S., Singh, M., Winkler-Moser, J. K., Liu, S. X. (2011). Organogel Formation of Soybean Oil with Waxes. Journal of the American Oil Chemists' Society, 89 (4), 639–647. doi: https://doi.org/10.1007/s11746-011-1953-2
29. Davidovich-Pinhas, M., Barbut, S., Marangoni, A. G. (2016). Development, Characterization, and Utilization of Food-Grade Polymer Oleogels. Annual Review of Food Science and Technology, 7 (1), 65–91. doi: https://doi.org/10.1146/annurev-food-041715-033225
30. Davidovich-Pinhas, M. (2019). Oil structuring using polysaccharides. Current Opinion in Food Science, 27, 29–35. doi: https://doi.org/10.1016/j.cofs.2019.04.006
31. Demirkesen, I., Mert, B. (2019). Recent developments of oleogel utilizations in bakery products. Critical Reviews in Food Science and Nutrition, 60 (14), 2460–2479. doi: https://doi.org/10.1080/10408398.2019.1649243
32. Sanz, T., Quiles, A., Salvador, A., Hernando, I. (2017). Structural changes in biscuits made with cellulose emulsions as fat replacers. Food Science and Technology International, 23 (6), 480–489. doi: https://doi.org/10.1177/1082013217703273
33. Mao, L., Lu, Y., Cui, M., Miao, S., Gao, Y. (2019). Design of gel structures in water and oil phases for improved delivery of bioactive food ingredients. Critical Reviews in Food Science and Nutrition, 60 (10), 1651–1666. doi: https://doi.org/10.1080/10408398.2019.1587737
34. Marangoni, A. G., Garti, N. (Eds.) (2011). Edible Oleogels: Structure and Health Implications. AOCS Press. doi: https://doi.org/10.1016/C2015-0-02413-3
35. Toro-Vazquez, J. F., Morales-Rueda, J., Torres-Martínez, A., Charó-Alonso, M. A., Mallia, V. A., Weiss, R. G. (2013). Cooling Rate Effects on the Microstructure, Solid Content, and Rheological Properties of Organogels of Amides Derived from Stearic and (R)-12-Hydroxystearic Acid in Vegetable Oil. Langmuir, 29 (25), 7642–7654. doi: https://doi.org/10.1021/la400809a
36. Taguchi, K., Toda, A., Hondoh, H., Ueno, S., Sato, K. (2021). Kinetic Study on Alpha-Form Crystallization of Mixed-Acid Triacylglycerols POP, PPO, and Their Mixture. Molecules, 26 (1), 220. doi: https://doi.org/10.3390/molecules26010220
37. Dichtyar, A., Fedak, N., Pyvovarov, Y., Stepankova, G., Yarantseva, Y. (2017). Research of the effects of technological factors on the quality indices of high oleic sunflower oil. Technology Audit and Production Reserves, 5 (3 (37)), 40–48. doi: https://doi.org/10.15587/2312-8372.2017.112912
38. Hwang, H.-S., Singh, M., Bakota, E. L., Winkler-Moser, J. K., Kim, S., Liu, S. X. (2013). Margarine from Organogels of Plant Wax and Soybean Oil. Journal of the American Oil Chemists' Society, 90 (11), 1705–1712. doi: https://doi.org/10.1007/s11746-013-2315-z
39. Singh, A., Auzanneau, F.-I., Rogers, M. A. (2017). Advances in edible oleogel technologies – A decade in review. Food Research International, 97, 307–317. doi: https://doi.org/10.1016/j.foodres.2017.04.022
40. Scholten, E. (2019). Edible oleogels: how suitable are proteins as a structurant? Current Opinion in Food Science, 27, 36–42. doi: https://doi.org/10.1016/j.cofs.2019.05.001
41. Bemer, H. L., Limbaugh, M., Cramer, E. D., Harper, W. J., Maleky, F. (2016). Vegetable organogels incorporation in cream cheese products. Food Research International, 85, 67–75. doi: https://doi.org/10.1016/j.foodres.2016.04.016