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ТЕХНОЛОГІЯ БІСКВІТНОГО НАПІВФАБРИКАТУ З ВИКОРИСТАННЯМ ЕКСТРУДОВАНОГО КУКУРУДЗЯНОГО БОРОШНА

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Монографія стосується дослідження впливу використання екструдованого кукурудзяного борошна на якість, харчову цінність, органолептичні та фізико-хімічні властивості та тривалість зберігання бісквітного напівфабрикату.

У монографії узагальнено результати досліджень щодо теоретичного та практичного обґрунтування технології борошняних кондитерських виробів, яка базується на використанні продуктів переробки зернової сировини методом екструзії. Обґрунтовано раціональний вміст основних рецептурних компонентів та технологічні параметри виробництва бісквітних напівфабрикатів з використанням екструдованого кукурудзяного борошна, у тому числі напівфабрикатів «Без глютену». Розроблено рекомендації щодо їх використання в технології борошняних кондитерських і кулінарних виробів.

Монографія рекомендована для наукових співробітників, аспірантів, студентів, які навчаються за напрямом 181 «Харчові технології» ОПП «Харчові технології в ресторанному господарстві», «Технологія хліба, кондитерських, макаронних виробів і харчових концентратів», а також для спеціалістів. В хлібопекарській промисловості та ресторанних господарствах.

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THE TECHNOLOGY OF SEMI-FINISHED SPONGE PRODUCTS USING EXTRUDED CORN FLOUR

Monograph

Ternopil – 2022

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The monograph summarizes the research results on the theoretical and practical justification of the technology of flour confectionery, which is based on the use of products of processing of grain raw materials by extrusion. The rational content of the main recipe components and technological parameters of production of biscuit semi-finished products with the use of extruded corn flour, including semi-finished products «Gluten-free» has been substantiated. Recommendations for their use in the technology of flour confectionery and culinary products have been developed.

The monograph is recommended for researchers, graduate students, and students studying in the field 181 «Food Technology» OPP «Food Technology in the restaurant industry», «Technology of bread, confectionery, pasta, and food concentrates», as well as for professionals in the bakery industry and restaurants farms.

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CONTENT

INTRODUCTION

One of the most important task facing technology food and food industry of Ukraine in general, is to expand the range of technological usage of traditional vegetable raw materials, the implementation of innovations aimed at improving existing technologies to increase the quality and competitiveness of domestic food production without rising its value for providing the population of its country with food, including dietary consumption.

Today, one of the most effective approaches to creating high-quality, functional systems in food technology is the synergistic effect. The synergism of the components of the proposed food system is manifested not only by a simple summation but by the potentiation of the effect. Therefore, a promising direction in expanding the range of products of high nutritional value, functional and special purpose is the development of biscuit products based on non-traditional types of flour, including corn, which has not only unique dietary properties but also a number of properties that positively impact on qualitative indicators of biscuit semi-finished products.

The range of products based on semi-finished biscuit products indicates the demand of Ukrainian consumers for biscuit products and the trend towards increasing consumption of such products of import production. However, the choice of biscuit semi-finished domestic producers is quite limited and only sometimes matches consumer demand and nutrition requirements.

Biscuit semi-finished products has found a use for obtaining a wide range of flour, culinary, and confectionery products: desserts, cakes, pastries, rolls, and cake pops. The range of its use is determined first place technological factors and organoleptic indicators because it is well-combined with other baked semi-finished products (protein-whipping and sandy), as well as with most of the finishing semi-finished products.

Biscuit dough is a thermodynamically unstable foamy food system. Therefore, one of the essential technological tasks is the stabilization of the system during the formation of products. Increasing the level of competitiveness of these products is possible through creating highly efficient technologies that ensure high-quality products without increasing their cost. Implementing natural plant raw materials (processed products of the grain industry) will not only improve the quality, and nutritional value and expand the range of biscuits on the Ukrainian market but also allow the creation of products for dietary consumption.

Relevant in this direction is the use of traditional biscuit semi-finished products technologies of advanced methods of raw material processing, particularly the application of the extrusion process in flour preparation. Because flour is the primary raw material that has impact on the quality and nutritional value of the finished biscuit semi-finished products.

Analysis of scientific and applied work in the field of creating new flour products indicates that the application of different types of extruded flour in food production has great prospects. The presence of fundamental developments in the field of extruded flour indicates the possibility of its application in biscuit semi-finished products technology.

Problems of quality improvement, intensification and stabilization technological processes of obtaining confectionery products with a foam structure, particularly biscuit semi-finished products, are reflected in the works of A.B. Horalchuka, K.H. Iorhachovoi, V.M. Kovbasy, V.V. Dorokhovych, V.I. Drobot, N.I. Cherevychnoi, S.Ya. Koriachkinoi, I.V. Matvieievoi and other scientists proved the possibility of using extruded grain raw materials and its positive effect on the course of physicochemical and technological processes in flour products. However, the scientific substantiation of biscuit semi-finished technology with the use of extruded corn flour has not been revealed. Therefore, the development of biscuit semi-finished technology, which is based on the scientifically usage of extruded corn flour and will stabilize the foam system of biscuit dough to technological factors, improve quality and extend the shelf life of freshness of biscuit semi-finished products, enrich its nutrient composition by replacing of potato starch with extruded corn flour and opens the possibility of creating a gluten-free biscuit semi-finished products, is relevant.

Generally, conducting a set of analytical and experimental research on the creation of a biscuit semi-finished products and flour confectionery products based on it using extruded corn flour is relevant, and their implementation will optimize the technological process, increase food value, reduce production losses, production costs and selling prices, which is especially important in conditions of limited solvency of the population of Ukraine.

CHAPTER 1.
PROSPECTS OF USE OF FLOUR EXTRUDED IN BISCUITS SEMI-FINISHED PRODUCTS

1.1. Current trends of the expansion of the range of biscuits semi-finished products

Current market conditions put for producers of products nutrition task of introducing competitive technologies under the conditions of simultaneous improvement of consumer properties, an increase of nutritional value and updating of an assortment of foodstuff, creation of products of particular dietary purpose, particularly based on a biscuit semi-finished products.

In Ukraine, the confectionery market formed a long time ago. This segment is characterized by a high level of competition and a large number of confectionery companies, which leads to a wide range of products that are dynamically updated and conform to the needs of consumers. In the structure of confectionery production in Ukraine, more than half (55.3%) is occupied by various flour products. Chocolate and cocoa products together account for 23.6%. A large share of products in the confectionery market – Ukrainian production (about 95%), but imports in this segment show active growth. This is due to the growing interest of Ukrainian consumers in foreign sweets, which are perceived as better [1].

The range of products based on biscuit semi-finished products on the market indicates the demand of Ukrainian consumers for biscuit products and the trend towards increasing consumption of such products of import production. According to the Statistics bulletin «Production of industrial products by type in Ukraine» for the first half of 2021 the confectionery market continues to increase production, particularly the growth rate compared to the same period last year comprised 8.7% [2, 3]. However, the choice of biscuit semi-finished products of a domestic manufacturer on the market is quite limited and only sometimes meets the needs of consumer demand, and the requirements of nutrition.

Biscuit semi-finished products has found a use for obtaining a wide range of flour, culinary, and confectionery products: desserts, cakes, pastries, rolls, and cake pops. The range of its use is determined in the first place by technological factors and organoleptic indicators because it is well-combined with other baked semi-finished products (protein-whipping and sandy), as well as with most of the finishing semi-finished products.

Analysis of the Ukrainian market shows that production and sales of culinary and confectionery products are developing in several areas: improving consumer properties, ensuring product safety, varying shelf life, reducing cost and energy consumption, and expanding the range of products, which indicates the need to improve existing and develop new technologies for biscuit semi-finished products. However, the quality of prescription raw materials is only sometimes meets the technological requirements that provide the necessary structural and mechanical properties of the dough to obtain products with the planned quality indicators, which leads to the necessity to adjust the recipe and parameters of the technological process.

One of the promising ways to solve this problem is the purposeful use of ingredients that have a wide range of technological properties, which allows for improving the physicochemical and organoleptic characteristics of semi-finished products, provides them with new quality indicators, adjusts the nutritional value and chemical composition and extend the shelf life.

Many works by native and foreign scientists are dedicated to the study of extending the shelf life of flour, culinary, and confectionery [4–9]. Using high-protein plant additives, hydrocolloids (gums, arabinogalactans, pectins, modified starches, cellulose, and its derivatives), and other non-traditional components in confectionery, allows solving not only technological problems to improve quality but also to extend the shelf life. The usage of pectin in the biscuit semi-finished in the amount of 15… 30% of the total weight of melange and enzymatically modified grain oats product can increase the resistance of biscuit dough to mechanical action, reduce the technological process, increase the biological value of the biscuit semi-finished products and the shelf life of its freshness [10]. The introduction at the initial stage of beating the egg-sugar mixture during the production of biscuit 5% inulin extends its shelf life to 7 days [11].

There is a method of adding vegetable puree [12], which is adding before beating in the egg-sugar mixture of carrots, cabbage, or beet puree, in the amount of 5… 30% of the total mass of melange in the dough. Introduction to the egg-sugar mixture before whipping pectin-containing raw materials complicates whipping and reduces the stability and volume of the egg-sugar mixture, however, it helps increase the biological value of the biscuit semi-finished products and the shelf life of its freshness. Considerable interest is caused by using as a source of pectin, minerals (iron, copper, cobalt, zinc, fluorine), vitamins B and C, PP, and flavonoids – pumpkin powder. Pumpkin powder is added as a filler, mixed with flour in 5… 10… 15% of the total amount of flour. The biscuit semi-finished products obtained in this way is recommended for health and preventive nutrition [13].

Studies have been conducted on the possibility of using non-traditional types of flour to create composite mixtures in biscuit semi-finished products. It was found that the best organoleptic characteristics were biscuits with a content of 25% rice flour, 50% – oat and barley, and 75% – corn and millet flour. The disadvantage of this method is the need to use composite flour mixtures in the technology of fat-containing biscuit semi-finished products, which does not allow them to give a functional focus [14].

The usage of fine powder from grape seeds in the amount of 5... 30% by weight of wheat flour allows getting a semi-finished products with a well-loose lush structure, drier to the touch compared to a biscuit semi-finished products without additives, chocolate color, with a pleasant taste and aroma. The introduction of grape pomace to the recipe of biscuit semi-finished products contributes to the production of high nutritional value, enriched with dietary fiber, polyphenolic compounds, and minerals [15].

Adding to the recipe of biscuit semi-finished the powder from fruits, flesh with peel and hawthorn seeds – 3.5 and 3%, medlars – up to 5.7%, from berries and blackberry seeds – up to 5% by weight of dry matter contributes to the production of biscuits with good consumer properties and long shelf life [16].

The offered technology of butter biscuits with the use of the dietary supplement «Milk Thistle Meal» in the amount of 8% by weight of raw materials, which allows obtaining products with high organoleptic properties and physicochemical parameters within the regulatory documentation [17].

The positive effect of white barley flour malt on quality indicators of premium wheat flour, structural and mechanical properties of the dough, nutritional and consumer value of biscuits, and the processes occurring during the storage of baked semi-finished products has been shown.

The technology of biscuit semi-finished products using corn malt flour and pectin improves such technological indicators as the stability of biscuit dough, which plays an important role during substitution and the beginning of baking, reducing baking and, accordingly, increasing the output of biscuit semi-finished products, increasing their shelf life has been shown.

The calculation of the nutritional value confirms the increase of the quantity of biologically active substances in the biscuit semi-finished products, vitamins, and minerals; the presence of pectin gives health-improving nature to the product as the functional effects on the human body [18].

As an improver and to slow down the hardening of flour products are widely used soybean products, including soy deodorized low-fat flour obtained from meal, soy semi-low-fat flour, etc.

Research of qualitative characteristics of the finished biscuit cake of the semi-finished product showed that the use of soy semi-fat flour could increase the biological value due to a combination of animal and vegetable proteins, increase the content of vitamins and minerals, expand the range of finished products, improve organoleptic quality and rise by 25–40% the value of specific volume and porosity of baked biscuit semi-finished products [19].

The usage of non-baking types of flour during the production of biscuit semi-finished products allows not only to diversify taste qualities, to increase nutritional value, to expand the range of flour products, but also due to features of their chemical composition, the content of soluble and insoluble non-starch polysaccharides help to reduce the intensity of hardening of this group of products, to extend the shelf life [20].

There is a method of production of biscuit semi-finished products with peeled rye flour, which is mixed with water in a ratio of 3: 7, kept at a temperature of 20 °C for 1 hour, after which the mixture is whipped [21]. The proposed technology allows to expand the range of biscuit semi-finished products.

A method of obtaining an oil biscuit, which differs with increased nutritional value, reduced baking and cost, which uses a flour composition comprising triticale flour and barley flour in a ratio of 1: 3 and additives improvers – 0.3… 0.4% sodium chloride and 0.3… 0.4% of sodium acetate to the weight of all flour used [22].

Comprehensive research aimed at developing the scientific recipes and technologies for producing biscuit semi-finished products with non-traditional sources of vegetable raw materials – millet and triticale flour, functional complexes of Orafti®P95 and orange-ginseng syrup have been conducted by authors Matvieieva T.V. and Koryachkina S.Ya. [23]. It was found that the best rheological, organoleptic, physicochemical characteristics are samples with a replacement of 80% millet flour with millet and 10% sugar Orafti®P95, or orange-ginseng syrup.

Proposed amaranth biscuit technology semi-finished products based on amaranth flour [24]. In its composition, flour contains important micronutrients – essential amino acids, minerals, and vitamins. It was found that the number of essential amino acids, B vitamins, and unsaturated fatty acids in the amaranth biscuit was significantly increased compared to the main biscuit made of wheat flour.

The obtained organoleptic parameters showed that the biscuit made of amaranth flour allows getting the final product with a more uniform, thin-walled, elastic crumb than in the control sample. During storage, the product can be kept fresh longer due to more bound moisture than in the control sample. Analysis of gluten content in amaranth biscuits was 6 mg/kg, so the biscuit could be labeled as a gluten-free product.

The authors [24] improved the method of cooking a semi-finished biscuit products, in which adding amaranth flour in the ratio of wheat and amaranth flour as 3:1 leads to the growth of the nutritional value of the finished product. The use of amaranth flour in the preparation of flour compositions for the production of biscuit semi-finished products reduces the gluten of wheat flour and allows to obtain a crumb with a well-developed porosity structure. An increase of the mass fraction of amaranth flour in a mixture of more than 25% leads to a reduction of the porosity and specific volume of the studied semi-finished products, which is associated with an increase in the mass fraction of lipids whose content in amaranth seeds varies between 7… 10%, which leads to a decrease the stability of the foam structure of the biscuit mass of this prescription composition.

The addition into the biscuit dough of a complex improving additive of barley flour and a mixture of glycerin and acetate or sodium citrate (1.5% by weight of flour) improves the structural and mechanical properties of the finished products.

To expand the range and improve the quality of semi-finished biscuits products, the authors recommended using flour and grinding products of sorghum. The application of sorghum flour allows to replace in a cocoa recipe and to receive a biscuit with pleasant color and taste, with good porosity and low density.

One of the conditions for forming a stable foam structure is the need to reduce the surface tension of the liquid, which is achieved by adding surfactants into the biscuit. These substances often reveal related technological functions of foaming agents, stabilizers, and emulsifiers and are used in technologies of different whipping masses.

During the production of biscuit semi-finished products combination of certain surfactants allow to ensure maximum aeration of biscuit faster and decline egg consumption [23]. As a result, the cost of melange is reduced by 20% and sugar by 5%, without compromising the quality of products.

In order to make more efficient use of food waste production, the way of production of a biscuit semi-finished products is offered [23], in which squid juice is used as a foaming agent instead of egg`s albumen, therefore, a solution of protein formed during cooking of squid in its own juice. Thus, using squid juice helps reduce calories and increase the biological value of biscuit semi-finished products. However, this biscuit contains additional citric acid and has a limited shelf life and specific taste qualities, due to this it did not find wide using.

To reduce the caloric content of foods, complete exclusion or reducing the cost of egg products, extending the shelf life, there is a need to find alternative raw materials, for example vegetable and animal proteins from traditional and non-traditional raw materials [26, 27].

It is known that reducing the number of egg products in the recipe with purpose of more rational use of raw materials and reduction of energy consumption of biscuit semi-finished products is possible due to application in the technology of additives emulsifying or stabilizing action. Regarding this, the possibility of simultaneous change of 15% sugar with inulin gel or oligofructose which adding into the egg-sugar mixture before beating, and from 10 to 30% of melange with dry powder of inulin or oligofructose which adding into the mixture with flour and crumbs at the stage of kneading the dough was studied [27, 28].

In order to reduce the number of egg products and reduce energy value of biscuit semi-finished products there was developed a method of production [23], which involves the replacement of 25% of egg-sugar mixture with milk base (reduction of skimmed milk powder with water in a ratio of 1: 2). There is an increase in specific volume of finished biscuit semi-finished products by 12.2%, porosity by 5.1%, and the energy value decreases by 5.3%.

The authors [29] proposed a method of production of low-calorie confectionery products, including the preparation of flour-free biscuits, mousse, cream, a layer of fruits and/or berries, and/or vegetables, consistently located on top of each other, distinguish in that the preparation of flour-free biscuit use powdered milk, and as a sweetener for preparation of cream and/or biscuit, and/or fruit, and/or berry, and/or vegetable component, and/or their mixtures, and/or mousse using a natural sugar substitute. The technical result achieved is that the caloric content of the finished product in a standard portion (80… 170 g) is from 50 to 200 kcal, the taste of biscuit confectionery is preserved due to the use of these ingredients and allows to use such confectionery by pregnant women, allergy sufferers and people with diabetes mellitus.

The authors [30] developed a composition of ingredients for preparation of a biscuit semi-finished products, where the complete replacement of melange by y-product during the production of lysomucoid –dry albumin in the amount of 6.8… 11.2 weight percent and additionally contains a paste-like emulsifier Dimodan was carried out.

The technology and recipe of the biscuit semi-finished products functional purpose without sugar with using sunflower oil instead of butter, dried kelp and eggs with selenium have been developed. It is shown that the quality of biscuit products using kelp, chicken eggs with organic selenium and sunflower oil allows to obtain flour confectionery products with functional specified as therapeutic and prophylactic properties due to enrichment with vitamin E, iodine, selenium and other essential substances [31].

The problem of diet enrichment with minerals, vitamin E, as well as polyunsaturated fatty acids (PUFA) remains important. In order to solve this problem, a method for the production of butter biscuit «Poliarna Nich» with the addition of crushed sunflower kernels, which is a source of protein, minerals, PUFA, vitamin E and fiber was presented. At the stage of preparation of semi-finished products, 8… 15% of crushed sunflower seed kernel is added to the mass of total prescription raw materials with complete replacement of butter [32].

It is known that lupine seeds contain a valuable complex of essential amino acids, PUFA, vitamins, and dietary fiber, consumption of lupine products decreases glucose in the blood and the level of cholesterol. In many countries, lupine processing products are used as functional ingredients, for example, in gluten-free diet recipes. To create a biscuit semi-finished products for health and preventive purposes, it has been proposed to add lupine flour in the amount of 5... 7 wt. % [33].

For the preparation of dietary biscuit semi-finished products, a method of replacing the sweet component – sucrose with fructose in the amount of 15.5…16.0 wt. %, which is related to its high specific energy and easy digestibility [34].

The authors [35] developed a semi-finished biscuit product for patients with diabetes mellitus, in which maltitol is used as a sweet substance. The prototype for this semi-finished biscuits was a biscuit with xylitol 20.9%, but because it has a cooling effect, it was noted as undesirable for this type of product. The replacement of xylitol with maltitol (20… 30% of the total number of prescription components) is proposed, and it is possible to obtain a biscuit semi-finished products with appropriate organoleptic properties.

For the manufacture of biscuit semi-finished products by the authors, a composition with the addition of blueberry powder, obtained by drying blueberries and grinding them has been proposed. Blueberry powder contains protein, pectin, fatty acids, minerals and antioxidants, which enriches wheat flour products. Unsaturated fatty acids, particularly linoleic and oleic acids, help the body combat the consequences of stress, excrete carcinogens, regulate cholesterol metabolism and strengthen the immune system [36].

National University of Food Technology dieveloped several special enriching phytocompositions. In particular, phytocomposition «Zhemchuh», which contains powdered milk, skimed with the addition of calcium phosphate. It is proposed to add an enriching phytocomposition in the amount of 5… 10% of the total number of components, then the structure of the biscuit semi-finished products is more stable, the porosity is developed [37].

A method of making semi-finished nut-poppy cholesterol-free biscuits has been developed, including beating egg whites with added sugar, poppy seeds, and nuts [38].

Methods of production of biscuit semi-finished products of increased nutritional and biological value and extended shelf life, in which the biologically active ingredient is cryopowder from grape skin, cryopowder from grape seeds, cryopowder from grape pomace in the amount of 2… 6% to the total weight of flour are developed by scientists of Kharkiv University of Food and Trade [39].

A method of producing biscuit semi-finished products containing bioavailable calcium and iodine has been developed. But the disadvantage of this method is an excessive amount of easily digestible carbohydrates and the instability of the whipped dough to mechanical action, thereby the quality of the dough and finished products are being reduced [40].

In order to create a method of biscuit semi-finished products production of high biological value, enriched with iodine, a technology has been developed where at the stage of beating egg melange with sugar and with other components adding elamin and salt, and as an additive use stevioside. The advantage of this method is that the obtaining product contains half the amount of easily digestible carbohydrates. Surfactant properties of elamine improve physical and chemical properties of the dough, the quality of finished products and speed up the process of beating the egg-sugar mixture [41].

Summarizing areas for improving the technology of biscuits semi-finished products, it can be identified the main current trends expansion of the range and ways of development of innovative technologies of biscuit semi-finished products in the following areas:

- improvement of foaming ability and foam resistance of whipped egg-sugar mass in order to improve the quality of products;
- intensification of the process of obtaining a foam-like structure of biscuit dough;
- reducing of calories, increasing of biological value, providing dietary properties to finished biscuits;
- expanding the range of biscuit products due to regulation of its prescription composition;
- inhibition of hardening processes and an increase of terms of storage of products.

It should be noted that most of these problems can be solved comprehensively through the use of various food additives that differ in their chemical origin, structure, functional properties and nature of interaction with components of the formulation of products.

However, there is a need to develop biscuit technology semi-finished products, which will ensure the formation of the specified rheological characteristics, tolerance to fluctuations of technological parameters. To study the factors influencing the stable production and high quality of the biscuit semi-finished products, the peculiarities of the technological process of its production are examined.

1.2. Theoretical aspects of the formation of a dispersed system of biscuit dough

Biscuit dough is a complex dispersed system consisting of air bubbles separated by liquid films. In this system, the dispersed medium is an egg-sugar mixture, and the dispersed phase is air. The technological process involves the dispersion of an egg-sugar mixture, which is saturated with air bubbles. The result of the process leads to an increase in volume, the development of the inner surface of the system and the creation of a foam system [42].

The foaming process is difficult due to the combined influence of numerous physicochemical, physicomechanical and other factors. Regularities that determine the formation of foam significantly changes depending on the conditions of a particular technological experiment.

The main characteristics that comprehensively characterize the foam system are – the foaming ability of the solution, the foam's multiplicity, the foam's stability, and the foam's dispersion, that is, distribution of bubbles by size or surface area of the solution-gas per unit volume of foam.

Today, a significant amount of theoretical and hands-on aspects of obtaining foams, which characterizes the geometric shape of air bubbles and their stability is collected [43].

The structure of the pins is determined by the ratio of the volumes of the liquid and gas phase and depending on this ratio, the foam cells have a spherical shape or the shape of a polyhedron. Usually freshly prepared foam of egg-sugar mixture has a spherical shape of cells separated by thick walls of liquid, because the volume of the gas phase exceeds the volume of liquid more than 10… 20 times. In the process of foam aging, the spherical shape of the foam bubbles becomes multifaceted with thin flat films, due to the flow of liquid. At the same time, the specific surface of the foam changes due to the diffusion of gas from small bubbles into larger ones, due to the difference in capillary pressures.

It should be noted that the state of the foam with multifaceted cells is similar to equilibrium, so this foam is more stable than with spherical cells. However, by reducing the number of small bubbles, the total number of air bubbles in this volume of foam decreases, therefore the coalescence of the foam occurs, which reduces its stability [42, 43].

Egg melange is most often used as a foaming agent in the technological process of making a biscuit semi-finished products. Due to the saturation of the protein mass with air, by beating the denaturation of the native structure (unfolding of protein chains without destroying their covalent structure) of proteins occurs. In the process of denaturation of the protein, its three-dimensional structure is destroyed, the polypeptide chain is unfolded, as a result of which the denatured protein can take many random conformations, at the same time forming links between polypeptide chains with the creation of a two-dimensional or three-dimensional system which generally increases stability of foam [42, 43].

The stability of the dispersed system is explained by structural mechanical properties of adsorption layers and thermodynamic stability of liquid layers. These adsorption layers slow down the flow of liquid in the film, reducing the speed of their thinning. Also, these layers provide the foam film with high structural viscosity and mechanical strength, creating a framework that gives the foam certain physical and chemical properties of the solid body. The thermodynamic factor of the stability of foam is connected with the pressure which arises in a foam film with an approach between two foam bubbles. It was found that temperature changes from 10 to 25 °C and heating for 30 minutes up to 50 °C do not significantly affect the foaming ability of egg whites. At a temperature of 60… 65 °C, the volume of foam decreases. The stability of the foam with increasing temperature becomes lower. The optimum foaming for egg white is in the range of 20… 30 °C, and the optimum foaming resistance is 20 °C [44].

It is known that the dispersion of the foaming structure depends not only from the nature of the foaming agent, but also from its concentration. With increasing concentration of the foaming agent, the mass gains a higher dispersion, its structural and mechanical properties change in the direction of decreasing fluidity and increasing the ultimate kinetic shear stress [44]. Studies have been conducted and [43] shown that with increasing concentration of the foaming agent – the viscosity of the solution decreases and foaming improves, the density of foaming mass decreases due to more air drawn into the system.

As mentioned above, the technology of biscuit semi-finished products in industrial conditions involves the use of egg melange as a foaming agent, at the same time it is a source of moisture in the food system. The foaming ability of egg melange also depends on viscosity. The higher the viscosity, the less air it is saturated during beating, and therefore the lower its foaming ability. The optimal viscosity of melange, which will provide a high-quality biscuit semi-finished products, is 2.8… 3.0 Pa s, and the optimal temperature of its beating – 10… 20 °C has been found [43, 45].

To form a stable foam structure, counteracting the surface tension forces of the system must be weakened, which is achieved by introducing surfactants which have the ability to significantly reduce the surface tension at the interface. In order to solve this problem, a method of weakening the resistance of the surface tension forces of the system by using the emulsifier «Beating paste» in the amount of 2... 3% by weight of raw materials has been developed. «Whipping paste» is a complex multicomponent system consisting of emulsifiers of three types, sugar, water, propylene glycol, and potassium sorbic acid, the use of which allows make all the components according to the recipe at once without prior beating of eggs and sugar, reduces the duration of beating the biscuit mass to 10 minutes, increases the shelf life of the finished product [46].

According to the results of research [44, 45], the negative impact of yolk fats on the foaming ability of protein which can be explained of formation on the surface of its micelles of films of fat that prevent protein saturation with air. At the same time, the yolk is a stabilizer of the foam system.

A characteristic feature of biscuit is that it has other prescription components that significantly impact the quality of the biscuit semi-finished products.

The main component that significantly impacts quality biscuit semi-finished products is flour. Compared to the duration of beating the egg-sugar mass, kneading with flour lasts only a few seconds, but the flour significantly impacts the quality of the semi-finished products. The properties of gluten flour and its content significantly affect the quality of baked semi-finished products, because during kneading there is hydration of gluten proteins and longer kneading leads to tightening of the dough and compaction of the structure of the biscuit semi-finished products.

It is used in the technology of biscuit semi-finished products wheat flour with an average content of weak gluten 28... 34% [47, 48, 49]. In this case, the biscuit semi-finished products has a fine-porous, thin-walled structure, high structural-mechanical, taste properties, as well as higher elasticity and porosity, compared to a biscuit made from wheat flour with strong gluten.

Quality indicators of flour and its gluten fluctuate in wide range and require constant correction of technological modes of production and formulation of biscuit semi-finished products, mainly in order to reduce the gluten of baking flour.

The most common way to reduce and weaken wheat flour gluten is adding potato starch up to 25% by weight of flour in the recipe of biscuit semi-finished products.

It is known that during the addition of this component increasing the plasticity of the dough due to its increased ability to swell and lower retrogradation of starch paste compared to grain starch has been occurred. And this leads to improved structural and mechanical characteristics of finished products and increase their shelf life. It is established that in case of replacement of 30% of wheat flour with starch, the volume, structural-mechanical and taste properties of the biscuit semi-finished products improve, its shelf life increases. The quality of the biscuit semi-finished products is significantly improved in the case of adding high amylopectin starch in the amount of 8... 15% by weight of flour [47–49].

It is believed that quite promising supplements to biscuit semi-finished products can be modified starches (hydrolyzed, phosphate, extruded) [50].

Another prescription component that has a significant effect for the quality of biscuit dough and semi-finished products – there is sugar. In a complex colloidal biscuit dough system, sugar plays a role structurant and foam structure stabilizer with increasing system viscosity. The stabilizing effect of sugar is due to the dehydrating effect on the protein, which leads to the formation of a solid film, which increases the stability of the foam system of egg-sugar mass.

However, as shown in the works of some researchers [51, 52], sugar negatively affects the foaming ability of egg albumen. It is found that increasing sugar concentration in protein-sugar mass in the system over 50% reduces foaming the ability of the protein, but increases its stability, the duration of beating increases, and the volume fraction of the air phase and the dispersion of air bubbles decreases. Obviously, this is due to the destruction of the formed protein-air micelles by sugar crystals until their complete dissolution.

As long as sugar has a dehydrating effect, its presence limits the swelling of flour proteins, which is reflected in the physical properties of biscuit dough. The presence of sugar in the biscuit semi-finished products in quantities of 31... 37% by weight of the semi-finished products affects the taste and high caloric content of products, which limits the possibility of using the biscuit semi-finished products in the diet.

A study, which explains the reduction of the share of sugar in the technology of biscuit semi-finished products more than 10%, the quality of the biscuit is getting worse has been conducted by authors [23]. With 80% sugar content in the recipe, the specific volume decreases by 3.3%, porosity – by 2.5%, total elasticity – by 3.4%. Biscuit semi-finished products has a large thin-walled porosity and after baking settles slightly. It was found that reducing the sugar content by 10% allows obtaining a semi-finished biscuit products, which has a higher specific volume, porosity and total elasticity of the crumb compared to the control sample.

Thus, the analysis of features of receiving biscuit cake dough shows that it is a complex foam system capable of destruction quickly and needs to increase its stability. This requires consideration of scientific principles of regulation parameters of stabilization of rheological properties of biscuit cake dough.

1.3. Prospects for improving technological properties of grain products of extrusion processing

The performed patent search shows that today in Ukraine and other countries the use of extrudates of starch-containing raw materials are widely used in a variety of food technologies. Developments in this direction continue to develop rapidly. The method of extrusion alter starch-containing raw materials, secondary raw materials of the grain, meat, fish, dairy industry. As a result of extrusion, raw materials or ready-to-eat products with new properties are obtained [53–61].

Extrusion technology allows to expand the range of products in the bakery industry. Extrudates of soy, wheat, rye, corn is used to improve the quality of rye and wheat bread [62, 63].

Drobot V.I, Arsenyeva L.Yu. in cooperation with other scientists suggested a method for improving the quality of bakery products by adding to the dough 1.5% of extruded corn flour and starch. Adding these products improves the elastic properties of gluten and increases the dough's viscosity, resulting in increased volumetric yield of flat bread [63].

Nowadays, the extrusion method is widely used for alteration of various types of food raw materials in extruders, as a result the polymers and biopolymers exposed a number of physical and chemical transformations. The shape, structure, chemical composition and properties of the material has been changed [64, 65].

The use of extruded corn flour in the technology of biscuit semi-finished products should be considered technology of extruded corn flour production and influence of extrusion treatment on physicochemical, biochemical and microbiological parameters of raw materials.

An analysis of published works [56, 61–62, 66–68] indicates of profound changes in the properties of grain raw materials in the process of high-temperature extrusion, which can be divided into three main groups of changes:

- physical and colloidal (change of dimensional characteristics of raw materials, thermophysical, optical, sorption, texture and rheological properties);
- chemical and biochemical (destruction of starch with accumulation of low molecular weight dextrins, sucrose`s inversion, denaturation and destruction of protein substances, inactivation or activation of enzymes, improvement of digestibility, color change);
- microbiological (destruction of bacterial spores, bacteria and mushrooms).

During extrusion processing of food raw materials a mass is formed, which acquires plastic properties. The increase of temperature causes elongation and rearrangement of some polymeric structural compounds. Proteins under such conditions change significantly, partially denatured [68, 69]. Under the action of pressure and voltage, the globular shape of protein molecules changes so that it increases in length several times more than in diameter, and in some cases the globule is partially «untwisted» during compression through the channels of the matrix, in this case, the temperature at the outlet of the mass from the extruder should be such that there is a fixation of the energetically unfavorable state of the globule. The enzymatic attack of proteins doubles during this time [62, 68, 69].

Therefore, under the action of hydrothermal processing with proteins the changes occur, which are called – denaturation, namely intramolecular phenomenon characterized by a regrouping of internal bonds. There is a violation of the order of the internal structure of the molecule, which is characterized by changes in the physicochemical properties of proteins (solubility, viscosity of solutions, resistance to enzymes, etc.). This phenomenon is due to a large number of weak bonds in the protein molecules [70].

In the process of extrusion the qualitative composition of proteins changes: quantity of water-soluble proteins decreases, while salt- and alkali-soluble – increases [71].

Extrusion processing of protein materials is widely used to change their structure. Texturing includes the rearrangement of protein molecules into a layered mass with cross ligaments, which prevents further destruction by heat treatment. Along with the hydrophobic interaction of chains, the formation of hydrogen and disulfide bonds and interchain amide bonds, occur as a result of interaction at high temperatures of side amino and carboxyl groups and amino acid residues [72].

Only some of the protein is lost due to the deep denaturation, which leads to the rupture of peptide bonds, but the fractional composition of protein undergoes significant changes [73].

Analysis of research [69] of identify changes the fractional composition of buckwheat proteins in the process of hydrothermal treatment shows that with a slight change in the total amount of nitrogenous substances significantly changes the fractional composition of the protein. The protein of raw materials has approximately the same amount of globulins and prolamines, 8.8 and 9.1%, respectively. Albumins and glutelins are identified in significant quantities: 36.9 and 32.8%. During cooking, the content of albumin is significantly reduced – up to 15.7%, globulins – up to 3.2, prolamines – up to 3.1%. The content of the alkali-soluble fraction increased by 7.9%. Scientists explain this fact by the influence of high temperature due to denaturation the degree of solubility of proteins in different solvents decreases.

Therefore, the glutelin fraction increased possibly due to the partial dissolution in the alkali of denatured water and salt solvent proteins.

It is known that cereal grains contain alcohol-soluble proteins – prolamines. It is also known that prolamins contain a small amount of essential amino acids – lysine, tryptophan, threonine. The main protein of corn is prolamins and in smaller quantities albumin, globulins and glutenins. During the extrusion of corn flour there is a decrease in water-soluble proteins – albumins by 9%, however, – a slight increase in globulins, prolamines and glutenins [69].

The study [69] results of the fractional composition of proteins of extruded corn flour and premium wheat show that extrusion processing causes a slight decrease of the total protein content in the extrudates, but significantly affects the changes in the fractional composition of protein substances. The decline in solubility is due to non-covalent interactions between polypeptide chains and other components, with the formation of new amide and disulfide bonds but due to the exchange reaction. Moisture heat processing and mechanical impact cause partial structural unfolding of the protein. The thermal motion of peptide chains causes a break of hydrogen bonds between chains, simultaneously with the structural unfolding of proteins is their aggregation.

During the extrusion process, the amino acid composition also undergoes changes in products. Today in the literature the data about the decrease in the content of some amino acids, which may be associated with influence of high temperatures has been published. The most thermolabile amino acid is lysine. Its losses during processing reach up to 40%. The decrease of lysine content under harsh processing conditions is explained by the formation of reducing sugars due to the hydrolytic decomposition of starch and the Mayar reaction. Losses of other amino acids reach: arginine – 21%, asparagine and histidine – 14%, serine – 13%. Reducing of the content of amino acids, especially essential, reduces the biological value of extrusion products. The loss of some amino acids is explained by the formation of complex complexes between different raw materials components under the influence of elevated temperatures.It is established that extrusion processing of flour raw materials increases its shelf life due to partial inactivation of enzymes [69, 74, 75].

Thermal action on the components of the mixtures does not reduce their ability to digest in any type of processing, and for some mixtures, it even increases with the use of high-temperature extrusion. In almost all works on the study of nutritional and biological value of extrudates there is an increase in their value after extrusion [72, 76–79].

The changes that occur during extrusion are caused by the fact that fatty acids may stimulate changes in starch. Complexes of amyloses with fatty acids, which are formed during extrusion, can adversely affect the assimilation of the product, but they have no significant effect.

During extrusion, vitamins undergo certain changes. In Germany, a study of the influence of extrusion modes on vitamin content has been conducted. For processing the vitaminized mixture on the extruder found that vitamins B_1, B_6, B_{12} and folic acid are stored better at a moisture content of 17... 25%. Losses of vitamins B_1, B_6, B_{12} are almost the same as during baking bread, and losses of folic acid are slightly higher [80].

Changes occurring in flour raw materials during extrusion processing cannot be considered without study of properties of starch in the process of hydrothermal processing. The size of molecules, strength and compactness of grains, polysaccharide composition, and type of glycosidic bonds determine its physicochemical properties.

Unlike other biopolymers, the molecules of polysaccharides in starch are not chemically identical, although they consist of the same structural units. Amylose and amylopectin differ significantly in molecular weight and are more often in a 1: 3 ratio [81].

Polysaccharides in starch grains are interconnected, mainly by hydrogen bonds. Structural ordering in starch crystals is achieved due to hydrogen bonds that occur directly between the hydroxides of adjacent chains, or with the participation of a water molecule, which plays a significant role in forming starch crystals. With increasing mass fraction of moisture of starch, the degree of its ordering increases, while the number of hydrogen bonds also increases [73].

Starch grains have a heterogeneous strength structure, associated primarily with the peculiarities of starch synthesis. The presence of OH groups in starch polysaccharides provides mechanochemical stability of starch grains through hydrogen bonds [82].

In their natural state, starch grains are insoluble in cold water, almost do not swell, but absorb up to 50% of water. Processes of swelling and gelatinization of starch depend on the influence of external conditions – the speed of temperature rise, mechanical action, the presence of electrolytes, as well as grain size and condition of starch polysaccharides, which may be changed as a result of destruction or structure formation [83, 84]. The increase in temperature leads to the rupture of intermolecular bonds in the grains of starch, resulting in increased hydration of polysaccharides, and gelatinization of starch.

The gelatinization mechanism is a set of processes that includes swelling, destruction of starch grains, their partial dissolution and formation of a three-dimensional structure of single-phase dispersion. but, gelatinization of starch in the extruder is distinguished due to the presence of significant mechanical impact on the material, low moisture content and high processing temperature. Under such conditions, thermomechanical destruction of starch grains and their polysaccharide molecules occurs, while swelling and dissolution in water are limited [85, 86].

It has been found that almost all grain moisture (80% of the total content) – loosely connected. During extrusion processing under the influence of high temperatures, this water is converted into steam, and molecules of water have high kinetic energy and can penetrate into the middle of starch-containing raw materials and weakly bind by active centers of biopolymers [87]. All this causes plasticization of the mass, due to intensive mechanical mixing.

Due to insufficient moisture content of the mass in interaction with steam, starch swells and partially gelatinizes. This colloidal process is similar to that which occurs in bread crumbs during baking, where water-absorbing starch plays a significant role [87].

During the processing of starch-containing raw materials under high temperatures the decomposition of starch with the release gaseous substances, including carbon dioxide, carbon monoxide, as well as small amounts of volatile acids and aldehydes begins. Approximately 5% of starch is converted into gaseous products.

The analysis allows concluding that starch, which is 65... 70% by weight of dry substance of starch-containing raw materials under moisture, temperature, and mechanical stresses, undergoes complex transformations, which leads to changes in its physical and chemical properties. Amylose and amylopectin behave differently under the influence of high-temperature extrusion. Amylose, having a lower molecular weight and linear structure, can be influenced by mechanical destruction, which requires high temperatures.

Due to the size and branching of the molecule at low humidity processing, Amylopectin undergoes significant mechanical damage, and its size is decreased.

Extrusion starches are characterized by greater solubility, and less ability to stick together than gelatinized [79, 88].

Thus, one of the promising methods of increasing the technological value of grain products is the use of unique methods of technological processing of raw materials, in particular, extrusion. The high nutritional and technological importance of extruded flour raw materials is determined by the physicochemical transformations of the main constituent substances that occur in the process of extrusion processing. In particular, the stability of flour fats is increased due to the fact that enzymes such as lipase, which cause the bitter taste of vegetable fats, is destroyed during extrusion, and lecithin and tocopherols, which are natural stabilizers, remain active.

The fiber in the process of machining in the extruder is crushed, and the starch is partially dextrinized. In addition, under the action of temperature and pressure is the sterilization of raw flour, which increases its sanitary status and minimizes the negative impact.

1.4. Features of gluten-free manufacturing technology of flour confectionery

Celiac disease is a chronic disease that is characterized by damage of the mucous membrane of the small intestine by gluten – a vegetable protein contained in cereals. Cereal proteins consist of 4 fractions: albumins, globulins, prolamins and glutenins. The last two fractions are called «gluten». Gluten is a water-insoluble complex of proteins with a low content of lipids, sugars and minerals.

The treatment and prevention of celiac disease are based in elimination diet therapy – complete exclusion of products containing gluten or its traces from the human diet, the so-called gluten-free diet, which is prescribed for life.

In recent years, the number of people suffering from celiac disease. According to the World Gastroenterology Organization (WGO), the prevalence of celiac disease in the world is 1: 165 [89, 90], according to researchers in Sweden, 3.7 cases per 1,000 people, in Italy – 4.9, in Austria – 1: 476, in the west of Ireland – 1: 300, in France – 1: 100-200, in Australia – 1: 476. Very rarely celiac disease is found in Africa, Japan, China, where preference in food is given to gluten-free products based on sorghum, millet, rice. In Ukraine, celiac disease is very rarely diagnosed in Ukraine, although according to medical experts from the «Ukrainian Celiac Society», hundreds of thousands of patients who do not tolerate gluten. This is probably due to the diagnosis of celiac disease and various types of disease, of which only the classic type has obvious symptoms, and other types of disease, although they cause problems with human health, do not have easily diagnosed manifestations. In addition, gluten intolerance, which is not celiac disease, but a gluten-free diet is also mandatory.

The amount of gluten in foods for patients with celiac disease strictly regulated – no more than 20 mg per 1 kg of product.

Demand for gluten-free products has grown in recent decades. Number of consumers who have problems with digestion of gluten increased by about 10%. And although these people have different degrees of sensitivity to gluten, in general, their condition improves if you follow a gluten-free diet. Approximately 1% of the population suffers from gluten allergy [89, 90].

The composition of the diet of a patient with celiac disease depends on age and severity of the disease, but is based on the basic general principles: the hydrocarbon component is composed of the permissible cereals, potatoes, legumes, vegetables, fruits, berries; protein and fat – meat, eggs, fish, dairy products, vegetable and butter [91]. Therefore, in the diet of patients with celiac disease, specialized gluten-free products made from buckwheat, rice, corn flour, potato, corn or rice starches are recommended. The gluten content in such products, respectively to Codex Alimentarius (CODEX STAN 118-1979, ALINORM 08/31/26 para 64, appendix III should not exceed 20 mg/kg of product] [9–93].

Analysis of the literature showed that during the production of gluten-free products, mixtures of different hydrocolloids, the combination of which provides the desired technological properties of the dough and the quality of the finished products is used.

In [94] the study prescription formation of composition of gluten-free mixtures for baking on the basis of corn starch, which allows optimizing the ratio of structurants and leavening agents due to the synergism of their action with the subsequent introduction of flour in different proportions to expand the range of bread, cookies, pasta have been developed. Innovative technological methods of production of flour confectionery products from the developed mix for baking «Rice» are developed and experimentally substantiated.

According to research [95], it was found that during production of gluten-free products, particularly gingerbread, mixtures of different hydrocolloids, combinations of which provides the necessary technological properties of the dough and the quality of finished products are used. Potato starch, soy protein isolate and natural polysaccharide xanthan gum have been studied as systems of such hydrocolloids.

Classical recipes for gluten-free bread [96] are based on rice and corn flour in combination with protein isolates, mainly soybeans. As rheological correctors properties of dispersions (dough, finished product) use such hydrocolloids as xanthan, modified starches in the amount of 1... 3% by weight of flour. The main disadvantage of flour products according to the described recipes is the low nutritional value due to the high content of starch, low content of dietary fiber, vitamins and minerals.

According to the authors [97] improvement of flour technology confectionery should be based, firstly, on the study of chemical properties of different types of starch (including determining the ratio of amylose and amylopectin), and secondly, on the development of ways to enrich flour products with essential macro- and micronutrients. Modeling of gluten-free products should be carried out not only taking into account the combination of trace elements and biologically active substances, but also in technologically justified combinations that will contribute to the formation of consumer properties.

In order to create a special biscuit semi-finished products with special purpose, particularly for people with celiac disease and people whose celiac disease is combined with diabetes, use gluten-free flour (rice, corn and buckwheat) and lactitol instead of sugar [41]. However, lactitol also has a limited range of consumers because it has a laxative effect on the human body. The EU's Scientific Committee on Food has introduced the «average daily dose», up to 50 g.

The main problem of making gluten-free flour products is imitating the structure-forming properties of gluten-containing raw materials [97]. Since the biscuit semi-finished products is a structured dispersed system – foam emulsion, an important task for its creation is the formation of the necessary rheological properties that provide an adequate texture to the traditional product. In the technological aspect of solving this problem is to find the optimal ratio of structural components, the choice of conditions for the formation of a stable structure of the food system, its structural and mechanical properties, characterized by viscosity, elasticity, plasticity. In wheat flour the main structural component is gluten (gluten) and starch, for rye flour – non-starch polysaccharides and to a lesser extent – gluten.

As a rule, gluten-free flour mixtures are combined with four groups of food components:

- flour with a high content of starch and non-starch polysaccharides: rice flour, corn flour, oats flour and flour from pseudo grain (amaranth, buckwheat) and cereals (millet), sorghum flour, flax flour, peanut flour, lupine flour, etc;
- high-protein ingredients – soy isolates and concentrates, isolates of pea proteins, lupine, caseinates, whey protein concentrates;
- hydrocolloids – xanthan, guar gum, various types natural and modified starches (potato, corn, rice, sorghum, etc.), microbial polysaccharides;
- emulsifiers, leavening agents, flavoring ingredients – melange, lecithin, baking soda, salt, sugar, flavors, dyes, minerals.

Raw materials of these groups and its combinations in specific recipes of flour products are extremely diverse and are determined by the type and specified nutritional value of the product, chemical composition and technological properties of raw materials.

The structure of gluten-free food systems is formed by account of the first three groups of raw materials. Components of the fourth group, if they are part of the products, and in relatively small quantities, but have a significant impact on the structural and mechanical properties of the food system.

One of the promising ways to expand the range of gluten-free diet is used in technological processes of production of flour confectionery products of gluten-free types of flour. Basically, the range of gluten-free products is limited to everyday goods: mixtures for baking bread and bakery products, pasta and flour confectionery (cookies). Therefore, there is a task to expand the range of gluten-free confectionery products, namely products based on biscuit semi-finished products with the replacement of wheat flour by gluten-free non-traditional types.

Biscuits are very popular among the population of Ukraine. However, patients with celiac disease and people suffering from gluten intolerance such products can not consume. That's why a number of biscuits were developed using rice, buckwheat, corn flour. It is established that these types of gluten-free flour have different effects on the organoleptic and structural parameters of baked biscuits. Biscuits on buckwheat flour have a specific taste, the most optimal, neutral taste, have biscuits on rice flour. It should be noted that these types of flour have a more intense effect not on the organoleptic characteristics of products, but on their structural parameters [98].

Scientists led by Dorokhovych V.V. developed technology of special flour confectionery purpose (cookies, cupcakes, biscuits) with the use of gluten-free flour – rice, corn, buckwheat. The content of increasing the nutritional and biological value of flour products for the hospital, scientists used additives soy and pea flour, as well as soy malt flour and peas. Diabetes mellitus and celiac disease are often combined. Scientists of NUFT have developed technologies for cooking, cakes, biscuits with the use of gluten-free flour and sugar substitutes – lactitol, isomalt, fructose [98].

A number of gluten-free foods have been created: protein-free bread (GOST 25832-89), gluten-free bread (TU 8-22-61-88), pasta «Corn», «Rice», «Buckwheat» (TU 9149-001-17629737, TU 9149 -011-17629737), pasta «Protein-free» (TU 9149-006-17629737), mixes for baking «Corn», «Rice», «Buckwheat», «Protein-free» (TU 9195-002-17629737, 9195-013- 17629737), cookies «Sugar», «Flower mix», «Harmony», «Salty» (TU 9131-007-17629737). Research and development on the production of flour confectionery products from gluten-free mixes containing grain flour amaranth, soy, rice, corn or buckwheat flour [99]. In Ukraine, certified foods for celiac disease are manufactured by Dr. Schaer (Italy).

In order to increase the nutritional value of flour confectionery, a recipe for gluten-free cupcakes based on the cake «Capital» has been developed [100]. Replacement of wheat flour was carried out on flax and rice in a ratio of 30:70.

This sample had the most optimal chemical composition, and to enrich the cake with micronutrients, eggshell flour was introduced. The biological value of the flour product increased by 2.3%.

Expanding the range of flour confectionery, mainly rice flour, will help provide vital gluten-free foods. The development of sugar cookie recipes based on corn flour and rice flour in a ratio of 60:40, characterized by a pleasant taste, aroma and attractive appearance have been conducted [101].

In addition, expanding the range of gluten-free confectionery the study of possibilities the use of buckwheat flour and crushed quinoa seeds in the recipe for shortbread cookies has been devoted [102]. At the same time, wheat flour is replaced by buckwheat and quinoa in a ratio of 70:30, and the products have a pleasant taste and aroma of hazelnuts.

In order to form the structure of gluten-free bakery products, a study [105] of functional changes properties of gluten-free flour using physical modifications have been conducted. There are different types of physical modifications of gluten-free flour and an analysis of changes in the functional properties of flour under the influence of processing in the review. The influence of flour particle size, fine grinding, various methods of dry and wet heat treatment on the formation of the structure of gluten-free flour products has been studied.

The elimination diet during celiac disease treatment must be strict and uncompromising. To continue life, there is a need to develop a biscuit semi-finished products for special dietary consumption – gluten-free- which will meet the consumer's capabilities, tastes and traditions. An important condition for creating a prescription composition should be high nutritional and biological value along with the affordable price. Despite the fact that the manufacture of biscuits offers many additives, today the search for effective stabilizers for biscuit dough remains an urgent task.

Thus, an analytical review of existing technologies allowed to determine the prospects for developing the flour confectionery market based on the dough.

Production of biscuit semi-finished products is in stage of development and has great potential for introducing new technologies. Analysis of the theoretical aspects of the formation and stabilization of biscuit dough foam shows that in the technological process there is the need to find the optimal ratio of structure-forming components, the choice of conditions for the formation of a stable structure of the food system, its rheological properties. Using natural non-traditional raw materials leads to producing new generation products of high biological value, with improved consumer properties.

Analysis of existing approaches to the development of biscuit technology of semi-finished products, advantages and disadvantages of existing technologies of its production, allowed to find out the feasibility of using corn flour and flour mixtures based on it in the technology of biscuit semi-finished products and the possibility of making biscuit semi-finished gluten-free, which will expand the range of products for special dietary consumption.

CHAPTER 2.
SCIENTIFIC SUBSTANTIATION OF TECHNOLOGICAL BISCUITS DOUGH STABILIZATION PARAMETERS WITH THE USE OF EXTRUDED CORN FLOUR

2.1. Defining an innovative idea for the development of biscuits semi-finished products using extruded corn flour

Considering the directions of technological progress in food industries, which are determined particularly by the state policy in the field of healthy nutrition, economic and social changes in society, new technological opportunities and competition in the food market, there is a need not only to improve the technology of traditional food products, but to create products of new generation that meet modern requirements, enriched important nutrients and with an extended shelf life.

Biscuit semi-finished products are the basis or part of many flour confectionery products, and the significant demand of the population for these products allows to consider them important food products.

Biscuit semi-finished products – lush, fine-grained, with soft elastic crumb confectionery, which is obtained by beating egg melange with sugar, mixing the whipped mass with flour and subsequent baking of the dough.

A deterrent to the use of flour confectionery biscuit semi-finished products is an instability of the technological process, which leads to the need to add foam stabilizers, a short period of freshness. During the storage of biscuit semi-finished products, at the same time with changes in the structural and mechanical properties of the pulp, its taste and aroma change – which are important consumer characteristics.

The structural and mechanical properties, taste and aroma of biscuit semi-finished products are affected the quality of raw materials that are part of its recipe.

For the manufacture of biscuit semi-finished products food industry traditionally used baking wheat flour premium, the high technological potential of which in the biscuit dough, is not used rationally due to the fact that it provides a targeted reduction of the «strength» of the flour by adding potato starch.

Expanding the range of raw flour due to the identification of alternative sources that can completely replace starch and partially or completely replace wheat flour in order to use it in the bakery industry rationally is relevant, as confirmed by several studies [26, 31, 43–44, 106–107]. The presence of fundamental developments in the field of production and use of different types of extruded flour in food production indicates the possibility of its application in biscuit semi-finished products technology [53–58, 67–69, 109–110]. A possible solution to this problem is using extruded corn flour (ECF), a source of modified starch extrusion process, contains proteins that do not form gluten, and can be used in biscuits semi-finished products technology [108].

In view of the above, a working hypothesis of research is formulated – stabilization of rheological properties of biscuit dough, associated with the mechanism of redistribution of moisture, provided by the introduction of extruded corn flour, to improve the quality and expand the range of biscuit semi-finished products.

Given the above information, it is definitely innovative design idea (Table 2.1).

Technology improvement is based on the following conditions:

- ability of starch ECF to swell and form a stable starch paste, in order to stabilize the rheological properties of sponge cake and increase its resistance to technological factors;
- ability of starch paste ECF, to slow down the process of retrogradation, which will help extend the shelf life freshness of biscuit semi-finished products;
- possibility of complete exclusion of starch and partial replacement of wheat flour (WF) with ECF to increase the nutritional value and diversification of taste properties of biscuit semi-finished products;
- opportunities to develop WF gluten-free.

To substantiate the technological parameters of stabilization biscuit dough using ECF should be conducted follows complex of experimental researches:

- to conduct a comparative analysis of ECF and wheat flour by chemical and amino acid composition, biological value, on compliance with the formula of a balanced diet;
- to study the mechanism of foam stabilization, to investigate the dependence of the addition of ECF on the ratio of free and bound moisture in the biscuit dough;
- to study the influence of ECF content on the viscosity of biscuit dough due to the ability of ECF to swell and form a stable starch paste;
- determine the rational parameters of technology and develop recommendations for the use of ECF in biscuit semi-finished products technology.

Table 2.1 – Innovative design concept

Index	**Characteristic**
1	2
Name	Biscuit semi-finished products using extruded corn flour (WF using ECF)
Product concept	WF with using ECF, the technology is based on the stabilization of the rheological properties of biscuit dough, based on the properties of starch ECF, well-developed fine-grained structure of biscuit semi-finished products, by replacing starch on ECF balanced in chemical composition and nutritional value, WF using ECF technological properties which allow to use it as a basis for sweet culinary and confectionery products

End of the table 1

1	2
Basic organoleptic parameters	Biscuit semi-finished products of uniform fine-porous structure without traces of impermeability, the form is correct, the surface is homogeneous without damages and breaks, with accurately expressed taste and a smell of corn extrudates
Competitive advantages	The product for a wide range of consumers can be recommended for use in dietary consumption for the manufacture of culinary and confectionery products
Assortment	The formation of the range is achieved by using BKE in flour mixtures with high-grade wheat flour, biscuit semi-finished products using exclusively BKE
Terms and conditions of storage	The shelf life is at least 1 month from the date of manufacture at a temperature not exceeding 20 °C at a relative humidity of 70 ± 5%

2.2. Research of functional and technological properties of ECF

2.2.1. Comparative analysis of the chemical composition of wheat and corn extruded flour.

ECF was evaluated by organoleptic and physicochemical parameters. Organoleptic parameters are given in table. 2.2.

Table 2.2 – Organoleptic characteristics of wheat and extruded corn flour

Index	Wheat flour (WF) of the highest grade	Extruded corn flour (ECF)
Colour	White or white with a cream tint	Bright yellow with cream and muted yellow shades
Scent	Inherent WF, no foreign odors, not moldy, not musty	Inherent in WF, pronounced odor of corn sticks, no foreign odors, not moldy, not musty
Taste	Inherent WF, without foreign flavors, not sour, not bitter	Inherent in corn sticks, without extraneous flavors, not sour, not bitter
The content of mineral impurities	Not assumed	

As can be seen from the data in table. 2.2 organoleptic characteristics of ECF meet the requirements for flour used in the production of flour confectionery and culinary products. The average chemical composition of premium wheat flour and ECF are given in table. 2.3. Analysis of the data shows that the moisture content of the studied flour differs significantly from the premium wheat flour. The moisture content in ECF is on average 4... 5% less than the moisture content in high-grade wheat flour, and the starch content in ECF is 3% higher. The protein content is 5% lower compared to WF. A characteristic feature of ECF is the increased content of ash and fiber in comparison with wheat flour [69]. Thus, ECF contains ash 4.3% more than wheat, and the amount of fiber in ECF is – 1%, which is 10 times more than in wheat.

The table shows a comparison of the fractional composition of corn protein and its extrudate and wheat. 2.4.

Table 2.3 – Chemical composition of wheat and corn extruded flour

Product	**Content, %**					
	moisture	**proteins**	**fats**	**starch**	**ashes**	**fiber**
Extruded corn flour	9,0±0,01	6,1±0,02	8,1±0,02	70,9±0,03	4,8±0,03	1±0,02
Premium wheat flour*	14,5±0,03	11,4±0,05	1,08 ±0,04	67,7±0,05	0,5±0,03	0,1±0,01

**reference data.*

Table 2.4 – Fractional composition of corn grain protein of its extrudate and wheat

Sample	**Total protein content, %**	**Content, % of total protein**				
		albumins	**globulins**	**prolamines**	**glutelins**	**insoluble precipitate**
Corn	6,9	18,9	11,5	33,9	23,1	12,6
Corn extrudate	6,1	11,0	12,7	35,9	23,3	17,9
Wheat	11,3	16,5	6,8	28,0	32,4	6,1

During extrusion, the content of total protein in ECF decreases by 0.7% and there is a redistribution by fractions of protein substances: the content of water-soluble albumins decreases, but the content of globulins, prolamines and alcohol-soluble glutenins increases. Despite the presence in ECF of gluten fractions of protein – prolamine and glutenin, do not form gluten like wheat proteins, but have their own physical, chemical properties and biological value. This fact prompted not only to study the amino acid composition of ECF proteins, but also to consider the possibility of creating a gluten-free biscuit semi-finished products**.**

2.2.2. Study of nutritional and biological value of ECF

The balance of amino acid composition, and its primary structure, particularly the content and quantitative ratio of essential amino acids, is one of the most crucial indicators of flour's nutritional value.

Considering the content of amino acids in flour and comparison with physiological norms of nutrition, it was found that in most proteins of cereals the ratio of amino acids differs from the optimal one. Lysine, methionine and tryptophan deficiency are most common [87].

Extrusion process in ECF increases the availability of amino acids for assimilation, due to the destruction of secondary bond protein molecules. Due to the short duration of heat process, amino acids are not significantly destroyed [70, 111].

In order to determine the content and ratio of amino acids in ECF, a study of the amino acid composition of its proteins (Table 2.5) on an amino acid analyzer has been conducted.

The data in table. 2.5 shows that proteins of ECF contain almost all essential and replaceable amino acids, therefore they are complete. The amino acid composition of the test samples consists of 16 basic amino acids, including 7 essential and tryptophan. Comparison of the amino acid composition of premium wheat flour and ECF shows that the ECF exceeds in the content of the following amino acids: leucine, alanine, aspartic acid, and tyrosine by 3.5 ± 0.3%; 5.1 ± 0.2%; 4.6 ± 0.4%; 2.0 ± 0.5%, respectively.

The biological value of wheat flour and ECF in amino acid score compared to the amino acid score of the reference proteins are given in table. 2.6 [111, 112].

Table 2.5 – Amino acid composition of wheat flour and extruded corn [112]

Amino acid	Samples			
	Wheat flour		Extruded corn flour	
	The number of amino acids, mg %	Amino acid content, %	The number of amino acids, mg %	Amino acid content, %
Indispensable	3021	32,6	2087	30,0
Valine	471	5,0	207	3,0
Isoleucine	430	4,6	159	2,3
Leucine	806	8,6	845	12,1
Lysine	250	2,7	148	2,1
Methionine	153	1,6	133	1,9
Threonine	311	3,3	272	4,0
Tryptophan	100	1,1	-	-
Phenylalanine	500	5,4	323	4,6
Replaceable	6270	67,4	4883	70,0
Alanine	330	3,6	612	8,7
Arginine	400	4,3	253	3,6
Aspartic acid	340	3,7	579	8,3
Histidine	200	2,2	157	2,3
Glutamic acid	3080	33,15	1710	24,5
Proline	970	10,4	708	10,2
Serine	500	5,4	453	6,5
Tyrosine	250	2,7	308	4,4
Cystine	200	2,2	103	1,5
The total number	9291	100,00	6970	100,00
Albumen %	11,4		6,1	

Table 2.6 – Biological value of WF and ECF by amino acid score

Amino acid	Scale FAO/WHO		Wheat flour		Extruded corn flour	
	mg/ 1 t albumen	amino acid score	mg/ 1 t albumen	amino acid score	mg/ 1 t albumen	amino acid score
Valine	50	1,0	47	0,95	20	0,40
Isoleucine+ Leucine	110	1,0	134	0,122	100	0,90
Lysine	55	1,0	27	0,49	14	0,25
Methionine	25	1,0	10	0,43	13	0,52
Threonine	40	1,0	31	0,77	27	0,67
Tryptophan	10	1,0	10	1,0	-	-
Phenylalanine+ Tyrosine	60	1,0	89	1,48	63	1,05

Comparative analysis of the amino acid composition of the studied flour samples shows that ECF exceeds wheat in methionine content by 9%, and the content of phenylalanine together with tyrosine and isoleucine with leucine is close to the standard [113].

The more the product's chemical composition corresponds to the formula of a balanced diet, the higher its nutritional value. Data on the compliance of the chemical composition of ECF formula of a balanced diet are given in table. 2.7.

Table 2.7 – Correspondence of the chemical composition of ECF to the formula of a balanced diet

Indexes	Daily requirement	The degree of satisfaction of the formula of a balanced diet			
		Content in 100 g		% satisfaction	
		ECF	WF	ECF	WF
1	2	3	4	5	6
Proteins, g	85	6,1	10,3	7,2	12,11
Lipids, g	102	8,1	1,0	7,9	0,98
Starch, g	400	70,9	67,7	17,7	16,9
Cellulose, g	20,0	1,0	0,1	5	0,5

End of the table 2.7

1	2	3	4	5	6
Minerals, mg					
potassium	2500	141	122	5,6	4,9
calcium	800	20	18,0	2,5	2,2
phosphorus	1200	92	86,0	7,6	7,2
magnesium	400	38	15,9	9,5	4,0
iron	14	2,7	1,2	19,2	8,5
copper	2,0	2,1	0,4	105	20,0
zinc	10,0	5,0	0,7	50	7,0
manganese	5,0	4,0	0,57	80	11,4
Vitamins, mg					
B_1	1,7	0,38	0,17	22,3	10,0
B_2	2,0	0,07	0,04	3,5	2,0
B_6	2.0	0,25	0,17	12,5	8,5
PP	19,0	1,1	1,20	5,7	6,3
E	10,0	2,7	2,6	27	26,0

The obtained results of the nutritional value of ECF and its conformity with the formula of a balanced diet allow us to conclude that the degree of satisfaction of the formula of a balanced diet with fiber, iron, copper, zinc, manganese, vitamins B_1, B_2 and B_6 is higher in the experimental sample ECF compared with wheat flour [114].

Thus, a complex study showed that ECF is a complete product in terms of nutritional and biological value and it is not inferior to WF of the highest grade, contains proteins – prolamine and glutenin fractions, which do not form gluten like WF, but have biological value due to higher content essential amino acids such as leucine, threonine.

The above allows to recommend ECF for use in the production of biscuit semi-finished products, particularly to consider the possibility of developing a gluten-free biscuit semi-finished products. The conformity of the chemical composition of ECF to the formula of balanced nutrition confirms the expediency of replacing WF of high grade and starch with ECF in biscuit semi-finished products technology in order to increase the nutritional value and diversify the taste properties of flour confectionery products based on it.

2.3. Investigation of the state of moisture in biscuit dough using ECF

According to the formulated innovative idea, it is expected that obtaining of biscuit semi-finished products with partial or complete replacement of high-grade WF with ECF, which is determined by its technological parameters and ability to bind moisture with polysaccharides, which in the foam system of biscuit dough contribute to foam stabilization [115, 116].

The structure of biscuit semi-finished products and its properties during storage depend, in particular, on the ability of ECF and WF to bind and retain moisture, so it is advisable to investigate the effect of adding ECF on the moisture holding capacity (MHC) of flour mixtures.

The table. 2.8 shows the results of the MHC study of flour mixtures of high-grade WF and ECF in different ratios – WF: ECF – 95: 5, 90:10, 85:15, 80:20, 50:50, 0: 100 mass %. The table. 2.8 shows that with increasing the share of ECF in the mixture, the MHC increases for the sample with the content of ECF: WF – 20:80 mass % 2.5 times, and 3 times for the sample ECF – 100 mass %. This trend is explained, in particular, by the swelling of whole grains of starch due to the absorption and retention of moisture. ECF starch consists of whole granules, damaged granules, gelatinized starch, starch of polymers. All these components have different effects on the moisture-holding capacity of flour mixtures.capacity of flour mixtures.

Table 2.8 – Researching of MHC of flour mixtures of WF and ECF in different ratios

Samples	Index MHC (20±2°C), %
Control – 100 **mass** % **WF**	29±1,5
ECF:**WF** – 5:95 **mass** %	38±1,0
ECF:**WF** – 10:90 **mass** %	49±2,5
ECF:**WF** – 15:85 **mass** %	58±3,0
ECF:**WF** – 20:80 **mass** %	70±2,0
ECF:**WF** – 50:50 **mass** %	81±1,5
ECF – 100 **mass** %	93±4,0

Swollen starch grains have inside the void, where water penetrates, breaks and weakens some hydrogen bonds between the chains, which causes the expansion of starch grains, while free polymers of starch dissolve, forming a dispersed system [88].

In order to determine the effect of ECF on the intensity of moisture binding in the biscuit dough system, we conducted a study of the state of moisture by nuclear magnetic resonance (NMR).

The fig. 2.1 shows the results of measuring the amplitudes of the spin echo signal A for biscuit dough samples using ECF at different intervals t. Taking into account the mass of the dough samples, the figure shows the relative value of the spin echo amplitude. This description of the experimental data will allow a qualitative comparative analysis. Since the change in the intensity of the spin-spin relaxation signals of the studied samples is an indicator of the degree of water structuring in the systems, analyzing which can determine for each system the magnitude of the speed of the water structuring throughout the study period.

Figure 2.1. shows that the relative amplitude of the spin echo of all dough samples decreases rapidly as a result of changes in the interval t, which indicates the intensive binding of moisture by the dough ingredients. However, samples with ECF content are distinguished by lower values of the relative amplitude of the spin echo signal, which indicates an increase in the effect of moisture binding in the biscuit dough system in the presence of ECF. Obviously, the more intense moisture binding in the biscuit dough system is due to the properties of ECF starch, which it acquires during extrusion**.**

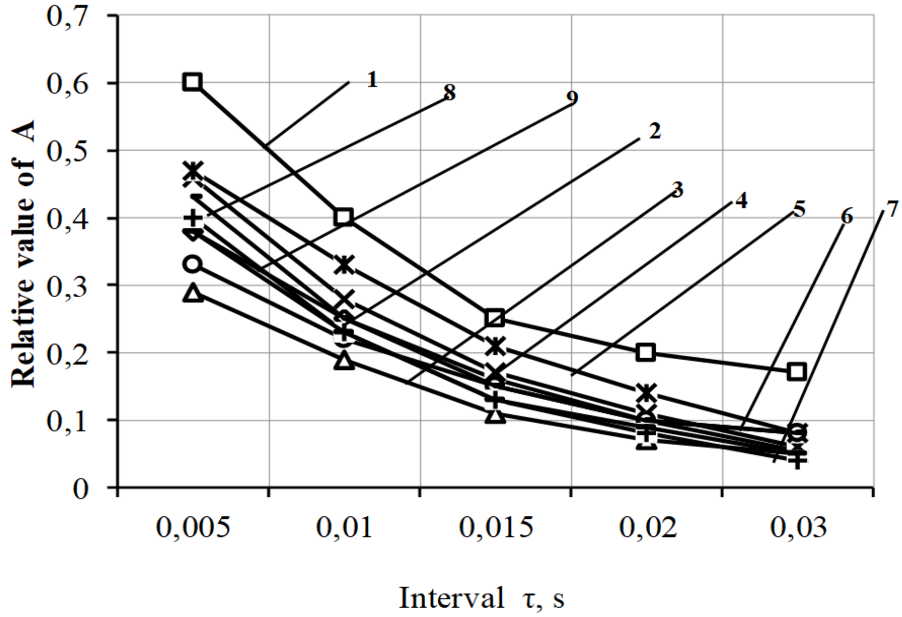


Figure 2.1 – Dependence of the amplitude of the spin echo signal from the interval τ between pulses for biscuit dough samples using ECF:
1 – 0% (control); 2–5 mass % ECF; 3–10 mass % ECF; 4–15 mass % ECF; 5–20 mass % ECF; 6–25 mass % ECF; 7–50 mass % ECF; 8–75 mass % ECF; 9–100 mass % ECF

The molecular kinetic characteristics of water during the determination of the spin-spin relaxation time T_2 were determined on the pulsed spectrometer-NMR device, which allow to obtain the information about the energy features of the behavior of water protons in biscuit dough: the degree of order and bonding strength of water molecules by itself. The results of the effect of ECF concentration on the value of the spin-spin relaxation time (T_2) are given in table 2.9.

Table 2.9 – Measurement results

Sample	**Time of spin-spin relaxation time, T_2**
Control– 100 mass % (WF)	0,029
ECF:**WF** – 5:95 mass %	0,025
ECF:**WF** – 10:90 mass %	0,024
ECF:**WF** – 15:85 mass %	0,023
ECF:**WF** – 20:80 mass %	0,022
ECF:**WF** – 25:75 mass %	0,020
ECF:**WF** – 50:50 mass %	0,019
ECF:**WF** – 75:25 mass %	0,019
ECF – 100 mass %	0,018

It was found that in samples of biscuit dough using ECF there is a general tendency to decrease the spin-spin relaxation time with increasing ECF content. This trend indicates a decrease in the mobility of water molecules due to the increased concentration of moisture-binding and moisture-retaining components of ECF, primarily modified in the process of extrusion starch ECF, which swells in the biscuit dough system and forms a stable starch paste. The change in the intensity of the spin-spin relaxation signals of the studied samples is an indicator of the degree of structuring of the water in the biscuit dough system. This leads to the conclusion that the increase in the amount of ECF in the biscuit dough system promotes the binding of moisture and it indicates a tendency to retain moisture in the finished product.

Thus, studies of the moisture-retaining properties of biscuit dough using ECF by spin-spin echo NMR have shown that the use of ECF will help stabilize the foam system of biscuit dough, namely: increase its resistance to mechanical action, that is stabilization of the process during pouring into molds and improving the quality of the finished biscuit semi-finished products [117].

In addition, the results of the study of the degree of water structuring in the biscuit dough system using ECF show the possibility of developing a gluten-free biscuit semi-finished products on its basis.

In general, the studies prove the feasibility of using ECF in biscuit semi-finished products technology, however, it is necessary to study the mechanism of its influence on the components of biscuit dough, particularly on the process of dough formation.

2.4. Study of the influence of ECF on the technological process of biscuit dough production

2.4.1. Investigation of the effect of extruded corn flour on the rheological parameters of flour mixtures

Grain proteins play an essential role in dough formation due to their high hydrophilic, elastic, and surfactant properties. It is recommended to use wheat flour with low or medium-quality gluten to prepare biscuit semi-finished products [48], otherwise, the crumb will be dense with underdeveloped porosity. Therefore, it is necessary to study the quality of raw gluten proteins of flour mixtures WF and ECF, as they affect the volumetric output and shape of finished products and their porosity structure.

For the experiment used wheat flour (WF) of the highest grade (control), extruded corn flour (ECF), and mixtures of these types of flour in different ratios – WF: BKE – 95: 5, 90:10, 85:15, 80:20, 50:50, 0: 100 mass %.

The effect of ECF on the deformation of gluten in flour mixtures was studied using the device gluten strain meter GSM-5. The results of the study are shown in Fig. 2.2.

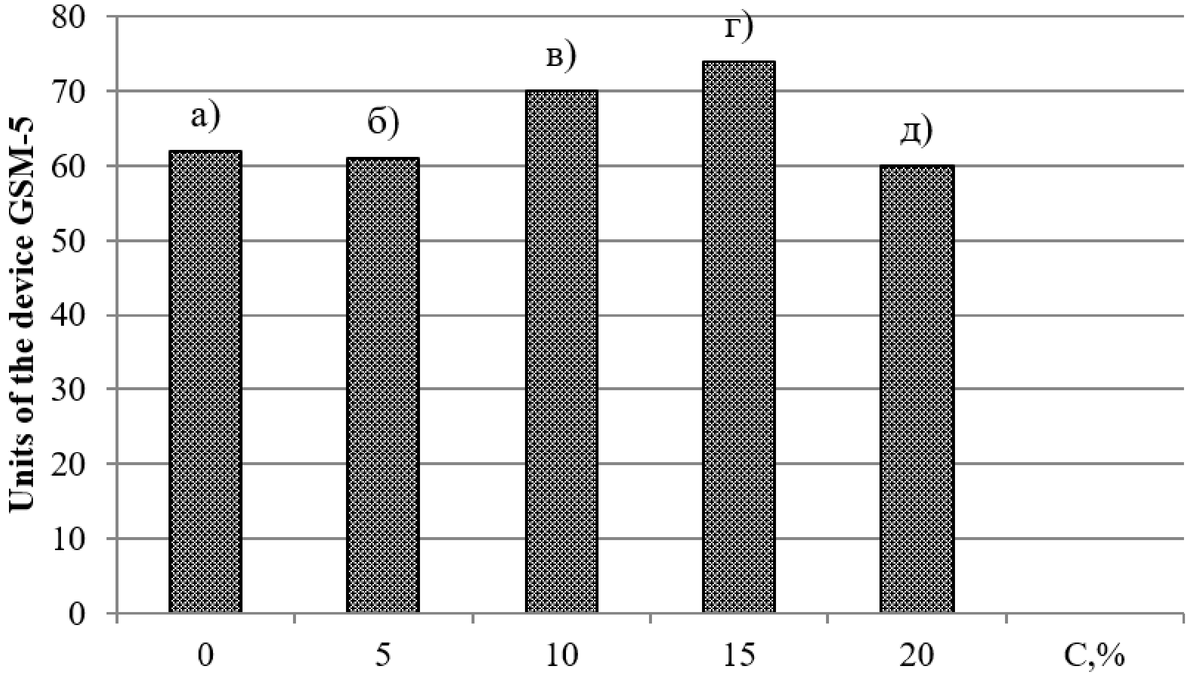


Figure 2.2 – Deformation on the gluten strain meter (GSM) of gluten flour mixtures from the content (C, mass.%) ECF:
a) WF: ECF – 100: 0 mass %; b) WF: ECF – 95: 5 mass %;
c) WF: ECF – 90:10 mass %; d) WF: ECF – 85:15 mass %;
e) WF: ECF – 80:20 mass %

Fig. 2.2 shows that with the addition of ECF to 15 mass % the compression ratio of the washed gluten increases by almost 23.3% compared to the control sample. The effect of improving the structural and rheological properties of gluten by adding ECF to 15 mass % is due to the properties that ECF starch acquires during extrusion. Samples WF: ECF – 50:50 mass %, 0: 100 mass % during washing did not form a homogeneous mass of gluten, the properties of which can not be investigated using the device GSM-5.

In the process of washing gluten, ECF starch quickly swells even in cold water and forms a starch paste, which enhances the structural and mechanical properties of gluten, as shown in Fig. 2.2. It should be noted that with a further increase of the content of ECF structural and rheological properties of gluten flour mixtures undergo minor changes compared to control, in particular for a mixture with ECF content of 20 mass % Compression remains almost at the level of the control sample [118].

A further increase of the concentration of ECF in the studied samples leads to a decrease of the amount of gluten and deterioration of its quality, which makes it possible to recommend such flour mixtures in the technology of biscuit semi-finished products, which require the use of low-gluten flour.

Besides gluten's rheological properties, the dough's characteristics based on flour mixtures, determined by using a Brabender farinograph, are important.

The obtained results are presented in the form of curves (Fig. 2.3), which register in the dynamics of a number of indicators – the time of dough formation, its stability, degree of vacuum, consistency and elasticity and reflect the technological properties of flour, and therefore allow to do conclusions about further use flour mixtures [119].

Samples with a ECF content of more than 20 mass % can not be examined on a Brabender farinograph, due to the dough's structural and mechanical characteristics. The lines of the diagrams are outside the range of study of the device and did not have the appropriate form for analysis.

Analysis of the obtained data shows that the addition of ECF changes a number of dough's parameters. With the addition of ECF there is a tendency to thin (P) (Fig. 2.3) dough to 190 units. etc., when in the control sample this figure is 40 units. etc., which may be a consequence of the dissolution of swollen starch grains, as well as the dissolution of dextrins formed during the extrusion of flour.

For biscuit dough, the dough's kneading time (T) is important. The width of the farinograph curve (G) indicates that the highest grade's elasticity and properties of the control WF are high. Adding more ECF leads to deterioration of the properties of gluten and elasticity – this indicates the feasibility of using ECF in the production of biscuit semi-finished products.

The positive point is that there is a decrease in the curves (C), which is much more pronounced with adding 5 mass % ECF, however, in the technology of biscuit semi-finished products specially used weak flour.

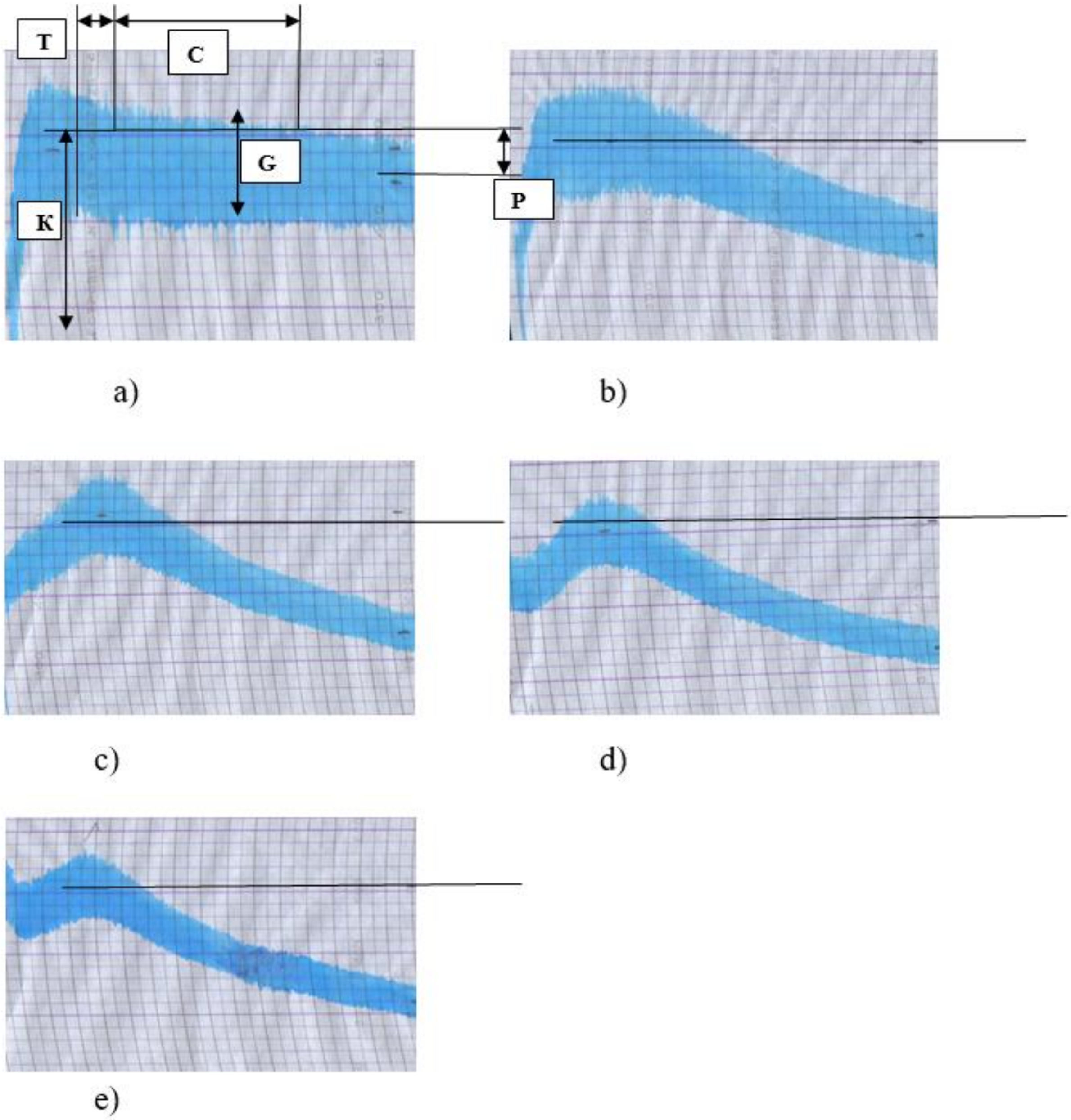


Figure 2.3 – Pharynograms of dough samples based on ECF and WF in the ratio of flour mixtures:

a) WF : ECF – 100: 0 mass; b) WF: ECF – 95: 5 mass %;

c) WF : ECF – 90:10 mass %;d) WF : ECF – 85:15 mass %;

e) WF : ECF – 80:20 mass %

However, the water absorption capacity (WAC) of the dough (Table 2.10) in the sample with a content of 20 mass % increases by 3% due to increased WAC of starch and ECF proteins, compared with starch and proteins of WF. The increase of WAC of flour suspension using ECF is explained, in particular, by changes in the fractional composition of ECF proteins.

The main protein fraction of corn is alcohol-soluble prolamins and in smaller quantities albumin, globulin and glutenin. During the extrusion of corn flour there is a noticeable decrease of water-soluble proteins – albumins, and a slight increase of globulins, prolamins, glutenins.

Table 2.10 – Rheological properties of the dough based on flour mixture with WF and ECF

Index	**Control**	**WF:ECF, mass %**			
		95:5	**90:10**	**85:15**	**80:20**
Indicators of the farinograph					
Crude gluten content, %	23,0±0,4	21,86±0,5	20±0,3	19,5±0,5	17,7±0,4
The amount of deformation of gluten	60±1,1	61±1,2	62±1,3	63,5±1,3	65±1,1
Water absorption capacity, %	53,0±0,5	54,3±0,4	54,8±0,4	55,5±0,5	56,3±0,3
The time of dough formation,	5,5±0,1	5,0±0,2	4,0±0,1	3,0±0,2	2,5±0,1
Dilution.	40±0,8	125±2,5	175±3,0	175±3,0	190±3,5
Valorimetric estimation according to Brabender	53±0,5	50±0,5	49±0,5	48±0,4	46±0,3
Dough humidity, %	10,4±0,3	10,8±0,2	11,2±0,4	11,5±0,5	11,8±0,4

Due to the moisture-thermal process and mechanical impact, there is a partial structural deployment of the protein. The thermal motion of peptide chains causes the hydrogen bonds between the chains to break, and their aggregation occurs simultaneously with the structural unfolding of proteins. This leads to an increase of WAC and dissolution of denatured proteins.

The graphs of alveograms (Fig. 2.4), shows that the value of the elasticity of the dough (P), which characterizes the stability and elasticity of the dough with the addition of ECF, decreases slightly.

The addition of ECF significantly affects the L – elongation of the dough. For comparison in the control sample L = 138 mm, and when adding 20 mass % ECF elongation is L = 78 mm, which is 42.3% less compared to the control. Therefore, the use of ECF reduces the elasticity and extensibility of the dough, but helps to optimize the value of the P/L ratio. It is known that the P/L ratio is 1.2… 1.3, which is typical for a dough with a well-balanced gluten quality [120].

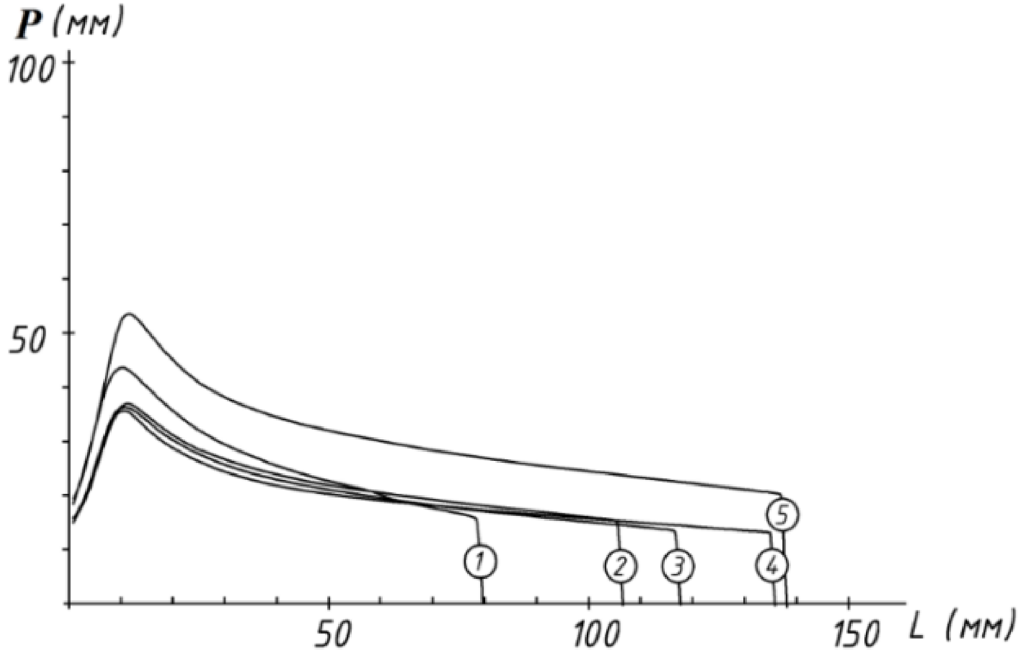


Figure 2.4 – Dependence of elasticity (P) and elongation (L) on the ECF content of the dough from flour mixtures (WF of the highest grade and ECF) in the ratio:

1 – WF: ECF – 80:20 mass %; 2 – WF: ECF – 85:15 mass %;
3 – WF: ECF – 90:10 mass %; 4 – WF: ECF 95: 5 mass %;
5 – WF: ECF – 0: 100 mass % – control

For the control sample, this ratio is 0.43 ± 0.02, namely wheat flour contains gluten with low elasticity and high elongation. However, the introduction of ECF in quantities of 5, 10, 15 mass % leads to an approximation of the elasticity and elongation, as seen in Fig. 2.5.

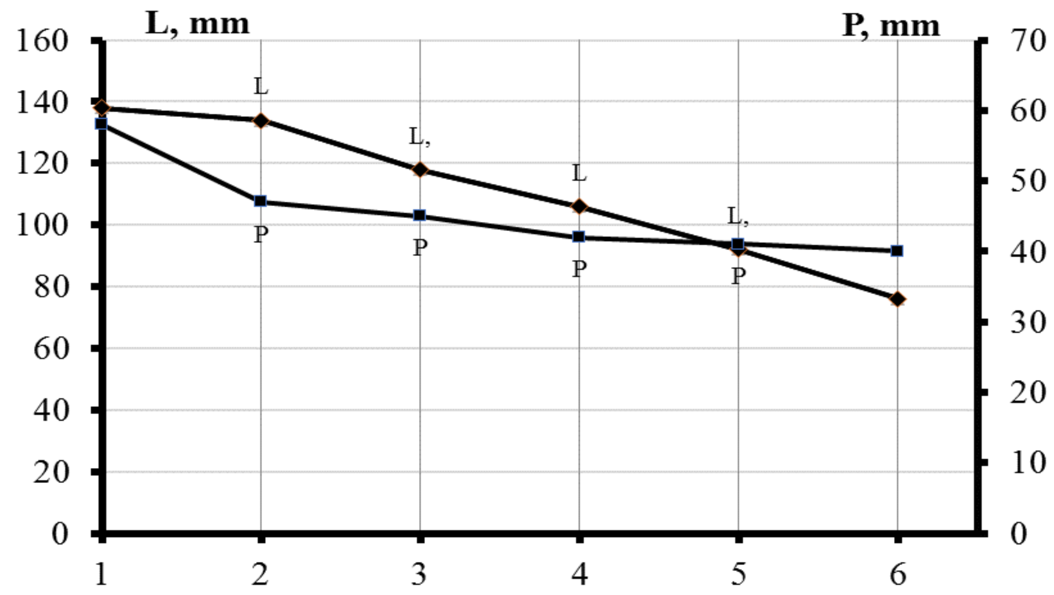


Figure 2.5 – Dependence of elasticity and extensibility of the dough on the content of ECF in flour mixtures (WF of the highest grade and ECF) choice in:
1 – WF: ECF – 100: 0 mass %; 2 – WF: ECF – 95: 5 mass %;
3 – WF: ECF – 90:10 mass %; 4 – WF: ECF – 85:15 mass %;
5 – WF: ECF – 80:20 mass %; 6 – WF: ECF – 75:25 mass %

As can be seen from Fig. 2.5 it is optimal to add ECF in the amount of 20 mas.%. It is in the zone of this concentration that the ratio is closer to the optimal (0.8… 1.6) for flour used to manufacture flour products. Studies have shown that the addition of ECF in the amount of 20 mass % increases the WAC of the dough by almost 3%, which is a prerequisite for improving the output of flour products by increasing the moisture content of the dough without compromising product quality and possible prolongation of its shelf life.

Thus, a flour mixture containing 20 mass % ECF can be recommended for biscuit semi-finished products because its adding leads to a weakening of the wheat flour gluten and eliminates the need for the adding of starch to weaken it. Therefore, the use of ECF increases the water absorption capacity of the dough, this fact prompted to investigate the effect of ECF on the properties of starch in flour mixtures.

2.4.2. Study of the influence of ECF on the properties of starch flour mixtures

Flour starch plays a significant role in the formation of the dough. The bigger the amount of starch (under the same conditions), the higher the benefits of flour. Cereal starch differs in moisture content, speed of saccharification, gelatinization temperature. Thus, the rate of hardening of flour products is associated with the moisture content of starch and the speed of hardening of flour products.

The nature of amylograms is influenced not only by the properties of starch, but also by the properties of the protein-proteinase complex and other components of flour. On the one hand, some studies suggest that the influence of these factors on the nature of amylograms is minor compared to the role and importance of the starch state. On the other hand, it is important to determine the nature of the process of gelatinization of starch in the flour. The behavior of pure starch isolated from the flour environment can differ significantly from its behavior directly in the flour and dough. Thats why the study's objects were premium wheat flour as a control, ECF and their mixtures in different proportions.

Amylograms of the swelling and gelatinization process are shown in Fig. 2.6, and their numerical indicators in table. 2.11.

Table 2.11 – The effect of ECF on the properties of starch flour mixtures

Sample	The gelatinization temperature, °C		Viscosity, units Brabender		Relative coefficient of stability,
	initial	final	η_{max}	η_{min}	η_{min}/η_{max}
100 mass % WF (control)	60±2	82±2	690±2	300±2	0,43
ECF:WF – 5:95 mass %	56±2	67±2	1100±2	300±2	0,27
ECF:WF – 10:90 mass %	55±2	65±2	920±2	340±2	0,37
ECF:WF – 15:85 mass %	53±2	63±2	740±2	300±2	0,40
ECF:WF – 20:80 mass %	53±2	60±2	580±2	280±2	0,42
ECF – 100 mass %	50±2	59±2	360±2	360±2	1,0

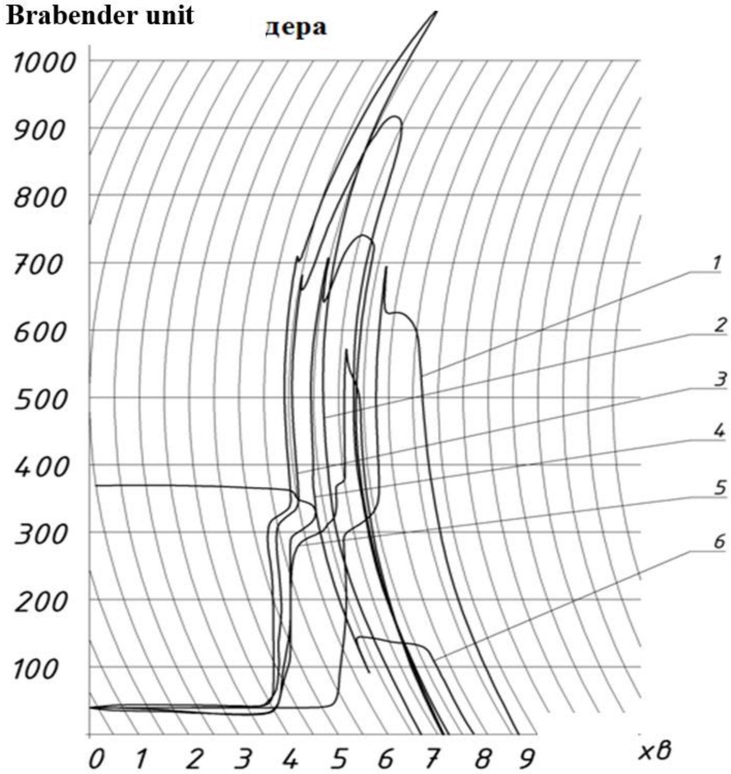


Figure 2.6 – Amylograms of flour mixtures from wheat flour (WF) and extruded corn flour (ECF) in the ratios:

1 – WF – 100 mass %; 2 – WF: ECF – 95: 5 mass %;

3 – WF: ECF – 90:10 mass %; 4 – WF: ECF – 85:15 mass %;

5 – WF:ECF – 80:20 mass %; 6 – ECF – 100 mass %

The change in the gelatinization temperature is an important indicator that characterizes the subsequent process of starch retrogradation during storage of finished products, because it is known that the lower the gelatinization temperature, the longer the products retain their freshness during storage. The temperature of the beginning of gelatinization, as can be seen from table. 2.11, for WF is 60 °C, and for ECF – 50 °C.

Thus, the use of mixtures of wheat and ECF in the production of biscuit semi-finished products will extend the shelf life of the last one, due to the initial gelatinization temperature of the starch suspension of the mixtures and ECF, which is lower than the control sample.

It should be noted that water-flour suspensions examined with an amylograph are viscoplastic thixotropic liquids, for which the value of viscosity is a function of shear stress. The thixotropy of the studied systems is manifested in the presence of local values of maximum and minimum viscosity, the ratio of which will determine the coefficient of stability of the system (k = ηmin / ηmax) to external factors (Fig. 2.6, Table 2.11).

It is found that for WF and mixture with ECF content of 5 mass % (Curves 1, 2) the maximum viscosity value (ηmax) is 690… 700 and 1000… 1100 units. Brabender, respectively, the minimum (ηmin) is 300 ± 2 units. Brabender. The decrease of viscosity indicates the degree of structural elements' destruction under mechanical destruction and thermolysis. ECF starch (curve 6) retains the same value of maximum viscosity for 6 · 60 s (ηmax = 360 Brabender units), indicating the structure's stability. Obviously, this is due to the fact that ECF starch due to the extrusion process acquires the ability to quickly and evenly swell and gelatinize at a lower temperature than wheat flour starch.

The dependence of the maximum viscosity of the suspension on the content of ECF (Fig. 2.6) allows to characterize the properties of biscuit semi-finished product using ECF during baking. The porous structure of the biscuit semi-finished products is fixed as a result of coagulation of gluten proteins and the conversion of starch into a thick paste. With the addition of 5 and 10 mass % ECF amylogram shows a high maximum viscosity, indicating starch binding during the gelatinization of large amounts of water. The result is a low-stretch starch paste and a dry sponge, prone to cracking [121].

By adding 100% ECF, the amylogram (Fig. 2.6) shows a lower maximum viscosity compared to WF, however, demonstrates the ability to maintain the maximum viscosity of the system [122].

Apparently, this is due to the fact that the starch during swelling and gelatinization binds enough water that is free in the dough and is released during the coagulation of protein substances necessary for the formation of moist pulp of the biscuit semi-finished products.

Since ECF is made by hot extrusion, the decrease of the viscosity of the flour suspension is due to the conversion of part of the starch into dextrins with lower viscosity. The decrease in the system's viscosity with increasing amount of ECF is also associated with a decrease in the proportion of gluten proteins in flour mixtures and the fractional composition of ECF proteins.

It is known that in the process of extrusion of corn flour there is a significant reduction in the amount of starch to 35% on the background of a significant accumulation of dextrins almost 20 times more than their initial amount. This process indicates profound changes in the structure of starch polysaccharides, which are associated with the rupture of glucosidic bonds. The destruction of starch during extrusion is due to thermal hydrolysis and mechanical destruction. In the first case, groups of dextrins are formed with a uniform degree of polymerization, because this process depends on the binding energy of molecules of glucoside residues, in the second case, the rupture of covalent bonds is random, so dextrins are formed with different amounts of glucoside residues. As a result of these processes there is an accumulation of a significant amount of water-soluble carbohydrates with different degrees of polymerization.

To substantiate the use of ECF in the production of biscuit semi-finished products and the possibility of complete replacement of high-grade WF on ECF, the density of biscuit dough was studied. Experimental average values of biscuit dough density using ECF are given in Fig. 2.7.

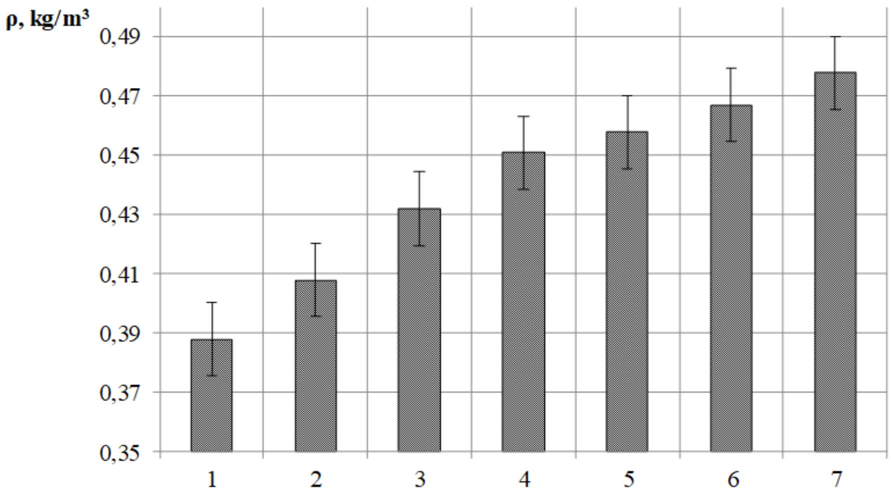


Figure 2.7 – Dependence of the density of biscuit dough (ρ) on the content of ECF in the samples:

1 – (control); 2 – WF: ECF – 95: 5 mass %;
3 – WF: ECF – 90:10 mass %; 4 – WF: ECF – 85:15 mass %;
5 – WF: ECF – 80:20 mass %; 6 – WF: ECF – 0: 100 mass %

It is found that with increasing the share of ECF in the flour mixture, the density of the dough increases. The optimal value of the density of biscuit dough is 0.444–0.446 kg/m3. Increasing the concentration of ECF above 20 mass % leads to a significant density of the dough, which is undesirable in the production of biscuit semi-finished products because it makes them thicker and less porous. However, the density of the biscuit dough, in the absence of wheat flour, indicates the possibility of creating a gluten-free biscuit semi-finished products, based only on ECF.

Thus, the influence of ECF on the properties of biscuit dough and biscuit semi-finished products is dictated, first of all, by the properties of the starch of corn flour that has undergone extrusion. The use of the obtained results will allow to regulate the technological properties of flour mixtures depending on the content of ECF in them and to recommend them in the production of biscuit semi-finished products, and to consider the possibility of using ECF in the technology of gluten-free confectionery based on biscuit dough.

2.5. The research of the influence of ECF on the microstructure of biscuit dough and biscuit semi-finished products

It was found that in the process of production of biscuit semi-finished products prescription components undergo physicochemical transformations, and interact with each other to form relationships, which leads to a change in the microstructure of the finished semi-finished products. In order to determine the mechanism of stabilization of the foam structure of the biscuit dough using ECF, we studied the changes in the microstructure of the biscuit dough and the finished biscuit semi-finished products.

The process of making biscuit dough is, in essence, beating the egg-sugar mixture, is to disperse the gas in the liquid. Considering the foam as a system that in the whipped mass contains mainly air bubbles, which are separated only by a thin film of liquid. Schematically, the structure of the foam can be represented as a package of gas bubbles with thin films of the main highly dispersed filler. This filler is covered with a film of substance with surfactants.

The whipped mass during biscuit semi-finished products production belongs to the plastic-viscous structured system. Its beating is accompanied by complex physicochemical, colloidal and mechanical processes. All of them are aimed at the formation of stable dispersed systems.

In fig. 2.8 in order to demonstrate the described structures that form the foam of biscuit dough, the comparative characteristics of the microstructure of the following samples are given: wheat flour (WF) and extruded corn flour (ECF) in the ratios: a) WF – 100 mass %; b) WF: ECF – 80:20 mass %; c) ECF – 100 mass %.

The quality indicators of flour and its gluten fluctuate in a wide range and require constant correction of technological modes of production and formulation of biscuit semi-finished products, mainly in order to reduce the gluten of baking flour.

The most common way to reduce the amount and weaken the gluten of wheat flour is the introduction of potato starch to 25% by weight of flour in the recipe of biscuit semi-finished products [123].

It is known that during the adding of potato starch, the plasticity of the dough increases due to its increased ability to swell and lower retrogradation of starch well compared with grain starch.

In fig. 2.8 in control sample (a), potato starch particles of larger size and oval shape, as well as WF starch particles with a finer composition, are observed. Sample (b) with ECF content of 20 mass % is characterized by the presence of only granules of WF starch. We have proposed a complete replacement of starch and part of the WF of the highest grade 20 mass % on ECF, as well as a complete replacement of WF on ECF for the manufacture of gluten-free biscuit semi-finished products.

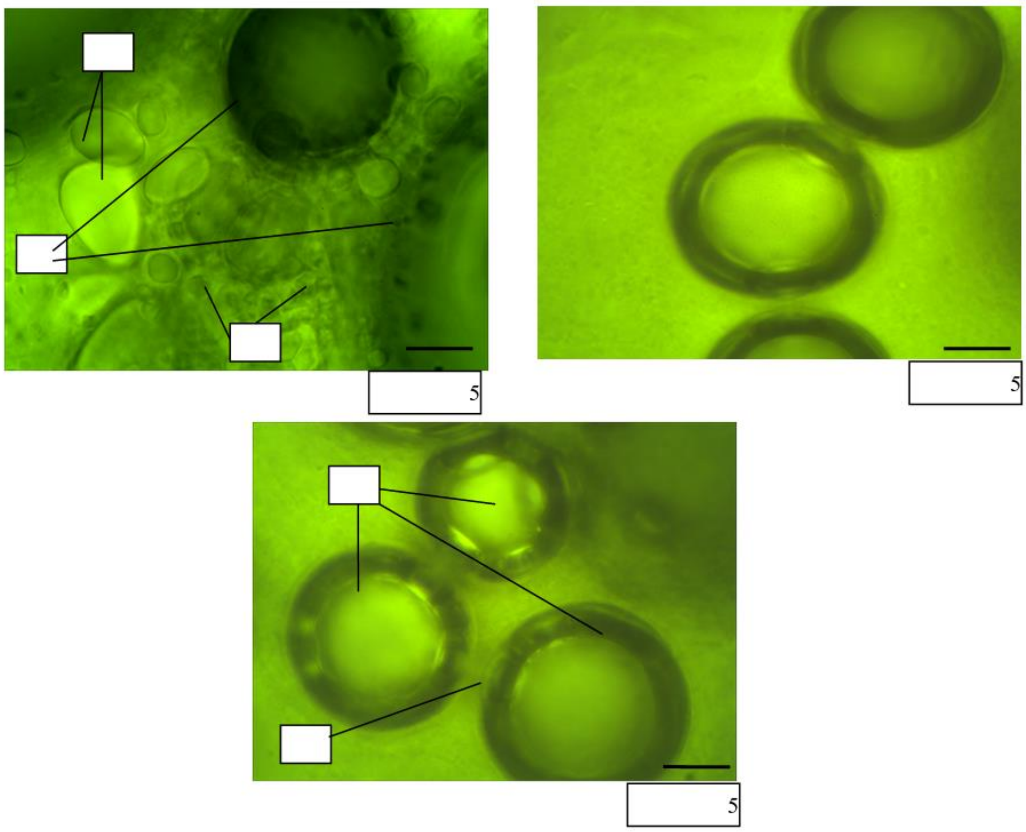


Figure 2.8 – Microstructure (1: 1000) of biscuit dough samples with the content: WF and ECF in the ratios:

a) WF – 100 mass %; b) WF: ECF – 80:20 mass %; c) ECF – 100 mass %;

1 – air bubbles; 2 – grains of potato starch; 3 – grains of starch of wheat flour;

4 – channels between air bubbles

These microstructures of biscuit dough show that the structure of the prototypes has the form of foam, the structural feature of which is the presence and uniformity of distribution of air bubbles, which later form a porous structure of biscuit semi-finished products. In the control sample (a) with the content of wheat flour and starch it is seen that the sizes of the formed air bubbles have a large difference in diameters, some bubbles are almost twice larger than others.

One of the causes of foam destruction is the diffusion of gas between the bubbles, and the pressure determines it in the middle of the bubbles. The destruction of the air bubble film is directed towards the larger bubble, because the pressure in it is less than in a small bubble. For comparison in the sample (c) of biscuit dough using ECF 100 mass % foam bubbles of almost the same size, in addition, it is noticeable that between them formed channels figs. 2.8 (4), which help to equalize the air pressure in the middle of the biscuit dough foam system, helps stabilize the foam system. For sample (b) with ECF content of 20 mass % is also characterized almost the same size of gas bubbles, and this leads to improved structural and mechanical characteristics of the finished biscuit semi-finished products.

To identify the role of the liquid phase of the dough during its short storage before baking, the stability of the formed foam was studied. This value is characterized by the speed of sedimentation of the foam. The results of the study are shown in Fig. 2.9.

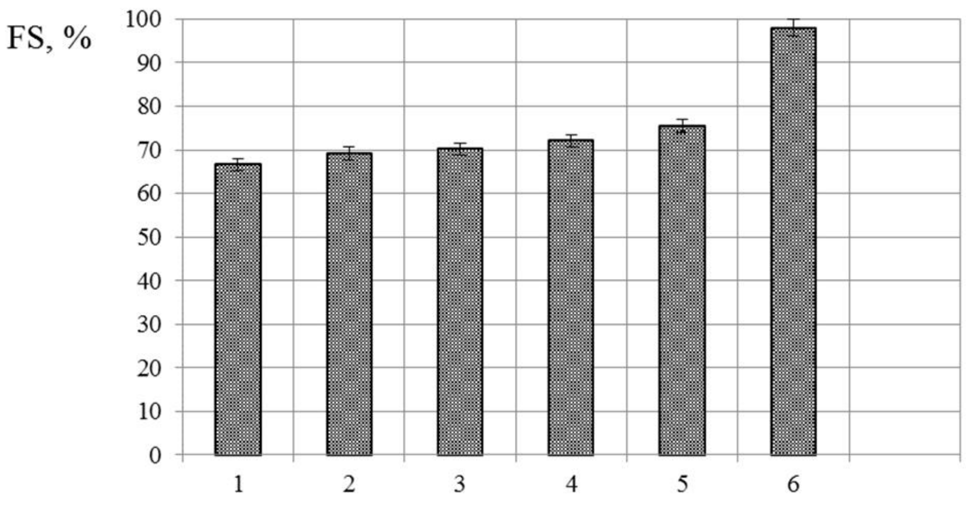


Figure 2.9 – Dependence of the stability of the foam of biscuit dough from the content of ECF:

1 – WF: ECF – 100: 0 (control); 2 – WF: ECF – 95: 5 mass %;
3 – WF: ECF – 90:10 mass %; 4 – WF: ECF – 85:15 mass %;
5 – WF: ECF – 80:20 mass %; 6 – WF: ECF – 0: 100 mass %

Experiments have shown that the stability of the foam depends on the flour which used. The addition of ECF in the technology of biscuit semi-finished products helps to reduce the movement of hydrophobic particles, which minimizes their negative impact on the stability of the foam. The high stability of the foam corresponds to the large volume and fine uniform porosity of biscuit semi-finished products.

It was found that the use of ECF instead of WF significantly affects the stability of the biscuit dough foam, this figure increases monotonically by almost 1.5 times with the complete replacement of WF with ECF. This ability will help stabilize the foam of biscuit dough and increase its resistance to mechanical action during its pouring into molds.

The use of beaten egg melange with sugar forms a stable system that settles slowly and gives a small amount of residue. Thus, studies have shown a settling time for the sample in Fig. 2.9 (a) is 120 · 60 s. This phenomenon can be explained by the caused flocculation, which forms large aggregates and sediment of large volume.

After baking samples (b), biscuit semi-finished products was obtained with a volume at the level of the control sample with a fine uniform porosity. The use of ECF helps to change the properties of a thick starch paste, which is plasticized so that a viscous dough is obtained. These data formed the basis for the development of biscuit semi-finished products technology «Sun» and «Gluten-free».

Therefore, starch gelatinization is essential for forming crumb of biscuit semi-finished products. Changing of the properties of starch in interaction with the emulsifier has a significant effect on the dough system. The formation of a fine-porous structure of biscuit dough using ECF 20 mass % And 100 mass % is due to the properties of ECF starch.

The photographs (Fig. 2.10) show that the biscuit semi-finished products structure has the form of a spatial grid. The results of the study indicate the presence and uniformity of pore separation in samples b) and c) using ECF, which is an integral part of the porous structure of biscuit semi-finished products.

An important factor in creating a new formulation of biscuit semi-finished products is and remains the study of structural and mechanical properties of the dough (viscosity, plasticity, elasticity, etc.). The study of these factors allows to purposefully carry out the technological process and obtain biscuit semi-finished products with the specified quality properties. Therefore, rheological factors that allow to formalize the technological operation of kneading and optimize further flow with a comprehensive assessment of the structure of the product need further study.

Thus, it is found that ECF in chemical composition corresponds to the formula of a balanced diet and is a full-fledged product in nutritional and biological value, which is not inferior to WF of the highest grade.

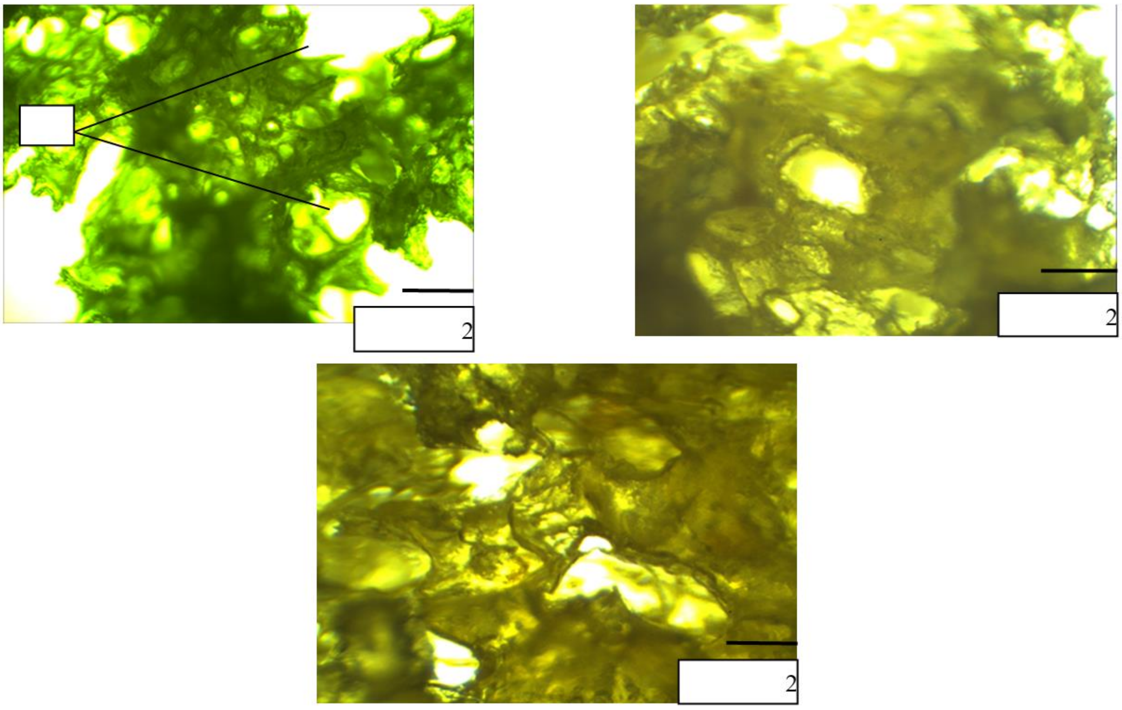


Figure 2.10 – Microstructure (1:40) of samples of biscuit semi-finished products with the content of WF and ECF in the ratio (1 – pores):
a) WF – 100 mass %; b) WF: ECF – 80:20 mass %; c) ECF – 100 mass %

It has been experimentally studied that the slowing down of the hardening process is due to the ability of ECF starch to reveal the properties of hydrocolloid, exerting a stabilizing effect, increasing the moisture holding capacity of dough, improving the volume outcome and structural and mechanical properties of biscuit semi-finished products.

It was found that the use of mixtures of WF and ECF in the production of biscuit semi-finished products will extend the shelf life of the lECF, because the gelatinization temperature of the starch suspension of the mixtures is lower than that of the control sample.

It was found that ECF in the amount of 20 mass % increases the moisture holding capacity of the dough by almost 3%, which is a prerequisite for increasing the outcome of flour products by increasing the moisture content of the dough without deteriorating the quality of the finished products.

During the study of the mechanism of foam stabilization it was found that the use of ECF promotes the redistribution of the ratio of free and bound moisture in the biscuit dough in the direction of increasing the amount of bound moisture, which affects the viscosity of biscuit dough and is based on the ability of ECF to swell starch paste, which indicates the possibility of creating a gluten-free biscuit semi-finished products.

CHAPTER 3. DEVELOPMENT OF TECHNOLOGY OF BISCUITS SEMI-FINISHED PRODUCTS USING EXTRUDED CORN FLOUR

3.1. Study of the influence of ECF on the characteristics of biscuit dough

Flour mixtures with using ECF have qualitatively new properties, which allows to recommend them for use in the production of biscuit semi-finished products in order to produce high quality products, expand the range, stabilize the process due to the ability of ECF starch to swell and form a stable starch paste, which helps stabilize foam of biscuit dough and increase its resistance to mechanical action. It has been experimentally proved (Section 2) that the presence of ECF in the amount of 20 mass % in mixtures with wheat flour reduces the «strength» of gluten, and for 100 mass % ECF increases the moisture holding capacity and the stability of the foam of biscuit dough.

To study scientifically recipes and technological modes of production of biscuit semi-finished products using ECF, it is advisable at this stage to study the influence of ECF on the rheological parameters of biscuit dough and baked semi-finished products and changes that occur during baking and storage of baked semi-finished products.

3.1.1. Research of the effective viscosity of biscuit dough using ECF

One of the most important indicators of biscuit dough as a foam system is the viscosity of the dough. It determines the fluidity of the biscuit dough, the resistance of its movement to the action of external forces, which characterizes its behavior during the technological operation «pouring into molds». High structural viscosity determines the dough's mechanical strength, creating an elastic framework that gives the system the physicochemical properties of a solid. The stability of the dispersed system, which is a biscuit dough, is mainly due to the viscosity of the initial solutions and their stress resistance.

Since the proposed adding of ECF to the prescription mixture affects the stability of the system, a series of experiments was conducted to study the dependence of the effective viscosity of biscuit dough samples with the addition of

ECF on the speed and tangential shear stress. The results of the effect of adding ECF on the effective viscosity of the dough are given in table. 3.1 range of shear rate Dr 0.3... 25.0 c-1. Analysis of the obtained data allows to identify the following patterns.

Table 3.1 – The effect of ECF concentration on the effective viscosity of the biscuit dough

Samples	Shear rate Dr, c^{-1}							
	0,89	**2,08**	**3,86**	**8,02**	**9,60**	**10,40**	**11,65**	**24,19**
Control – 100 mass % WF	31,86±1,0	13,4±0,6	6,50±0,3	4,35±0,2	3,90±0,2	4,18±0,2	4,13±0,2	4,02±0,2
ECF:WF – 5:95 mass %	26,96±1,0	10,6±0,5	4,92±0,3	4,30±0,2	4,69±0,2	3,93±0,2	3,82±0,18	3,80±0,18
ECF:WF – 0:90 mass %	25,98±1,0	10,4±0,5	5,37±0,3	4,43±0,2	4,39±0,2	3,88±0,2	3,71±0,18	3,57±0,15
ECF:WF – 15:85 mass %	24,51±1,0	10,0±0.5	5,20±0,2	4,22±0,2	4,29±0,2	3,71±0,2	3,38±0,13	3,20±0,13
ECF:WF – 20:80 mass %	24,02±1,0	9,77±0,4	5,09±0,2	3,97±0,2	3,67±0,2	3,27±0,2	3,03±0,13	2,92±0,13
ECF:WF – 100:0 mass %	22,06±1,0	9,13±0,4	4,75±0,2	3,40±0,2	2,93±0,2	2,83±0,2	2,48±0.12	2,14±0,1

The results of the flow values of all samples show a decrease in viscosity with an increasing shear rate. The test's most intense decrease is observed based on a mixture with content of ECF 100 mass % at a shear rate of 2.4s-1. A further decrease in the effective viscosity with increasing shear rate is less intense, and all samples tend to approach a constant viscosity of 4.2 ± 0.2 PAs for the control sample and a viscosity of 2.4 ± 0.12 PAs in the sample with the content of ECF 100 mass % at a shear rate γ 11,65 s-1. This change in viscosity with increasing shear rate is due to the destruction of the foam system of the biscuit dough. With a further increase in the shear rate γ (12.0… 25.0) s-1, the viscosity of all samples remains at the same level as at the shear rate γ 11.65 s-1.

The study results show that the addition of ECF helps reduce the biscuit dough's effective viscosity. Thus, at a minimum shear rate of 0.89 c-1, the effective viscosity of the biscuit dough for all samples with ECF content is less than the effective viscosity of the control sample by an average of 15… 25%. It was found that at a shear rate of 8.02 s-1 shear stress in the sample with a maximum ECF content of 100 mass % relative to the control sample decreases by 33%, at the same values of shear rate the structure failure occurs at lower values of tangential shear stress. That is, due to the higher water absorption capacity of ECF, its addition destabilizes the structural and mechanical properties of the foam structure of biscuit dough due to the rarefaction of the system.

In fig. Figure 3.1 shows the rheological curves of the shear stress τ (Pa) on the shear rate γ c-1 for biscuit dough samples under conditions of using BCE of different concentrations. As can be seen from Fig. 3.1 rheological curves of all dough samples have the same shape, the nature of the change in viscosity characteristics of biscuit dough is the same for all samples. But at each point of determination at the same shear rate (γ, c-1), the shear stress (τ, PA) has lower values for the sample with 100 mass % BCE content compared to the control sample. And at a shear rate of 24.4 s-1 for all samples, the shear stress is not determined, which indicates the destruction of the foam system of biscuit dough.

A characteristic feature of all test specimens is an active increase in tension at a shear rate of up to 9.60 s-1 with a subsequent increase in shear speed there is a gradual increase in stress to the point of failure. From the obtained results it can be assumed that the action of the working bodies on the mixture of components during the kneading of the dough occurs at low energy consumption, and this effectively affects the production of quality products.

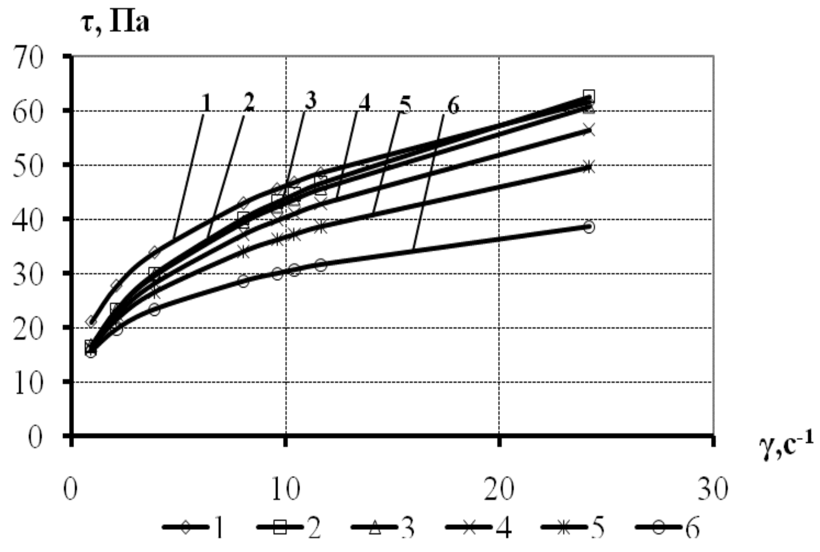


Figure 3.1 – Dependence of bias voltage, (τ, PA) on speed of shear, (γ, s-1) for biscuit dough samples:

1 (control); 2 – WF: ECF – 95: 5 mass %; 3 – WF: ECF – 90: 10 mass %;
4 – WF: ECF – 85:15 mass %; 5 – WF: ECF – 80:20 mass %;
6 – WF: ECF – 0: 100 mass %

Thus, the obtained results of the study of the effect of ECF on the rheological parameters of the biscuit dough showed that the use of ECF leads to a change in the effective viscosity in the direction of its reduction, in the studied samples. Biscuit dough is a system that has its own structure and mechanical strength. Dispersed multicomponent systems can be presented in the form of a continuous medium in which the dispersed phase is concentrated. This phase is a particle that is differently arranged in a dispersed medium. Therefore, they are characterized by a nonlinear viscosity dependence on the deformation rate, and the value of the allowable shear stress τ0 is quite significant. As the shear rate increases, the plastic viscosity of such systems decreases significantly. The dependence of changes in the effective viscosity on the mass fraction of ECF in the composition of flour mixtures is observed. Increasing the shear rate in the range γ (12.0… 25.0) s-1 leads to a certain stabilization of the viscosity of the samples, especially in samples using 100 mass % ECF.

3.1.2. Study of the influence of ECF on the properties of biscuit semi-finished products after baking, aging and storage

The influence of ECF use on the indicators of the finished biscuit semi-finished products, which characterize the quality of the finished product (Table 3.2), was studied.

Table 3.2 – The effect of extruded corn flour on the properties of the biscuit semi-finished products

Indicator	**Samples of biscuit semi-finished products with the ratio, mass %**		
	WF: ECF – 100:0 (Control)	WF: ECF – 80:20	WF: ECF – 0:100
Humidity of the finished semi-finished product, %	20,6±0,5	21,6±0,5	25,1±0,5
Specific volume, cm^3/g	3,4±0,7	3,6±0,7	3,3±0,7

As can be seen from table. 3.2 the humidity of the finished biscuit semi-finished products using ECF increases to almost 25% with the complete replacement of WF with ECF. The increase in biscuit semi-finished products moisture with the use of ECF is explained by the difference in the mechanism of moisture retention in biscuit semi-finished products with high-grade wheat flour and ECF. That is, the ability of ECF to retain moisture more strongly, the removal of which requires more energy, respectively, a higher temperature than the baking temperature of biscuit semi-finished products. Baked semi-finished products has the highest value of specific volume (3.6 cm3 / g), if the concentration of ECF is 20 mass %. The specific volume of biscuit semi-finished products using ECF 100 mass % remains at the level of the control sample. Thus, the obtained results allow to generalize that the optimal content of ECF in the flour mixture that can be used for biscuit semi-finished products is 20 mass %, And there is a possibility of complete replacement of wheat flour ECF in biscuit semi-finished products technology.

The baked biscuit semi-finished products has a structure of solid foam. The loss of a certain amount of moisture during the baking of dough blanks leads to a decrease in their weight, the quantitative characteristic of which is baking (U), which significantly affects the output of finished products and causes technological losses during baking. This indicator is an important technological characteristic, because it depends on the output of finished products. The amount of baking of the semi-finished products depends on the temperature and duration of baking, the relative humidity of the air of the baking chamber, as well as the features of its recipe. Based on this, the effect of ECF on the loss of mass of biscuit dough during baking was studied, which was determined immediately after leaving the products from the oven. Samples of dough and finished products with the addition of ECF in the amount of 5, 10, 15, 20, 100 mass % to the total weight of flour were examined. As a control, the main biscuit was examined.

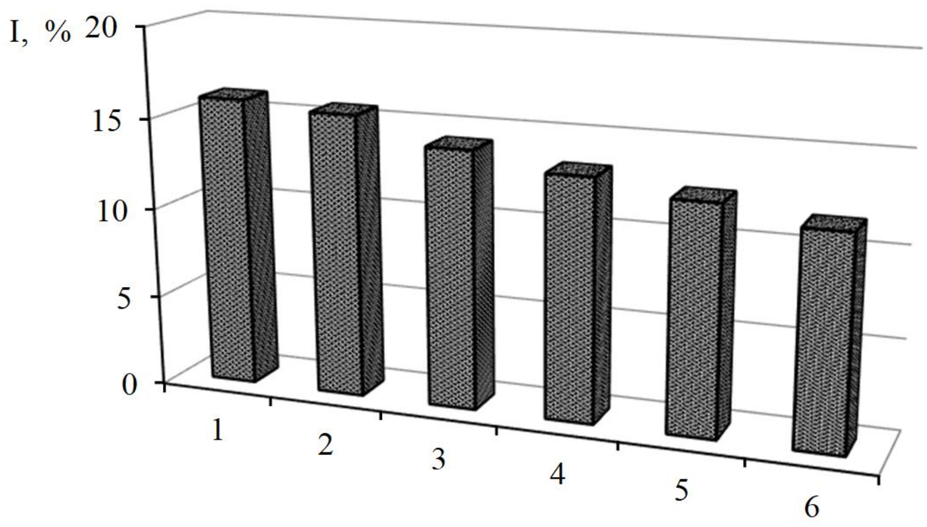


Figure 3.2 – The index of baking biscuit semi-finished products from the contents of ECF:

1 – (control); 2 – WF: ECF – 95: 5 mass %; 3 – WF: ECF – 90:10 mass %; 4 – WF: ECF – 85:15 mass %; 5 – WF: ECF – 80:20 mass %; 6 – WF: ECF – 0: 100 mass %

Thus, it was found that the addition of ECF reduces the weight loss of biscuit semi-finished products during baking. In particular, the addition of ECF in the amount of 100 mass % reduces the weight loss of products during baking by (20.0… 22.0)%. This is due to the hydrophilic properties of ECF to bind and retain moisture more strongly.

After baking, biscuit semi-finished products technology provides for its keeping at room temperature (15... 25 °C) for 6 · 602 s to fix the structure. At this time, there is a redistribution of moisture between the crust and the inner layers of the crumb and the loss of a certain part of it from the top layer. This creates a stable porous structure that allows cutting biscuit semi-finished products without deformation of the crumb. Therefore, the effect of ECF addition on moisture loss after standing at a temperature of (20 ± 1) °C after 8 · 602 s was investigated. As the humidity of biscuit semi-finished products with the use of ECF increases, we determined the loss of moisture (drying) after cooling (after 1 · 602 s). The results of the experiments are given in table. 3.3.

It is found that with the increase of the share of ECF decreases the weight loss of the semi-finished products after one hour by 8… 20%, and after eight hours by 18… 39%. Obviously, this is due to the ability of ECF starch to bind moisture and slower retrogradation of starch paste compared to higher grade WF, and is a prerequisite for slowing down the hardening process.

Studies of the ultimate shear voltage were performed on a penetrometer, which allows to measure the amount of deformation of the product during the action of voltage on it during storage (Table 3.4).

Table 3.3 – Moisture loss biscuit semi-finished products using ECF

Sample	Moisture loss (%)	
	$1 \cdot 60^2$ c	$8 \cdot 60^2$ c
Control 100 mass % WF	1,3±0,1	3,4±0,1
ECF:WF – 5:95 mass %	1,3±0,2	3,2±0,3
ECF:WF – 10:90 mass %	1,3±0,3	2,8±0,2
ECF:WF– 15:85 mass %	1,2±0,2	2,7±0,1
ECF:WF – 20:80 mass %	1,2±0,1	2,4±0,2
ECF – 100 mass %	1,0±0,1	1,6±0,1

Table 3.4 – Indicators of the shear voltage of the biscuit semi-finished products during storage

Sample	Shear limit voltage (σ_0×10^{-3}), Pa		
	10 days	**20 days**	**30 days**
Control – 100 mass % WF	0,073±0,003	0,126±0,004	0,198±0,006
ECF:WF – 5:95 mass %	0,073±0,003	0,121±0,004	0,198±0,006
ECF:WF – 10:90 mass %	0,072±0,003	0,116±0,004	0,187±0,006
ECF:WF – 15:85 mass %	0,071±0,003	0,114±0,004	0,171±0,006
ECF:WF – 80:20 mass %	0,068±0,002	0,111±0,004	0,160±0,006
ECF – 100 mass %	0,042±0,002	0,088±0,004	0,093±0,004

The process of hardening of semi-finished products with ECF is slower, as it was showed by comparative analysis of the shear voltage of the test and control samples during one month of storage. Thus, if for the sample with ECF content of 20% the device was 0.160 × 10-3 PA after 30 days of storage, then the control sample after 20 days. Thus, it was found that the shear voltage index after 30 days of storage was 11… 25% higher than in the control sample.

The increase in the shelf life of biscuit semi-finished products due to the ability of starch of ECF to exhibit hydrocolloid properties, exerting a stabilizing effect, and improving the physical properties of biscuit dough, increasing the moisture-binding capacity of the dough and slower retrogradation of starch paste during storage of biscuit semi-finished products.

An essential characteristic of the quality of baked biscuit semi-finished products is the porosity of the products, which significantly affects their ability to quickly and evenly impregnate with syrup and filling and determines the texture of the finished product. To determine the porosity of flour products, use Zhuravlev's device, which was used to determine the total porosity (Fig. 3.3).

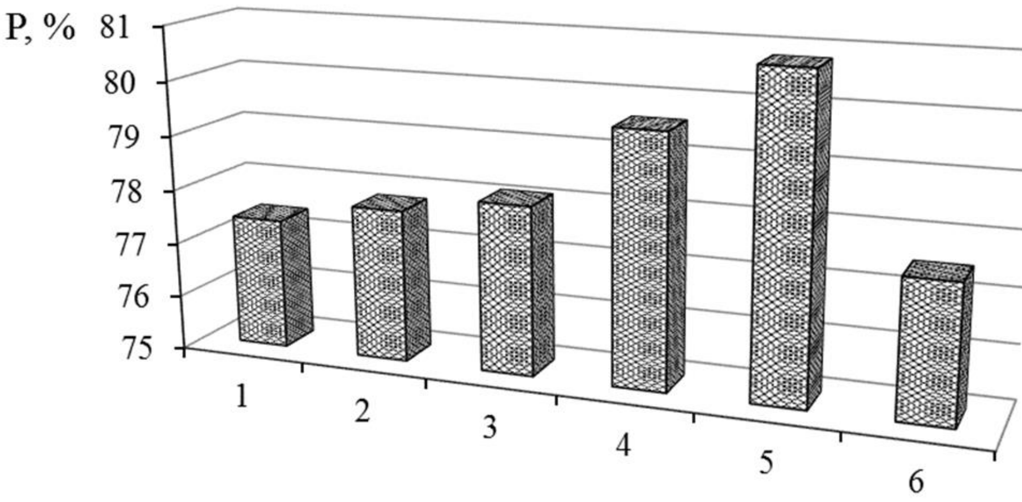


Figure 3.3 – The porosity of biscuit semi-finished products from the content of ECF:

1 – (control); 2 – WF: ECF – 95: 5 mass %; 3 – WF: ECF – 90:10 mass %; 4 – WF: ECF – 85:15 mass %; 5 – WF: ECF – 80:20 mass %; 6 – WF: ECF – 0: 100 mass %

The use of ECF helps to increase the porosity of biscuit semi-finished products by 2… 4% and, with the addition of ECF 100 mass % Porosity is slightly reduced, but remains at the level of the control sample. The decrease in the porosity of biscuit semi-finished products with the use of ECF more than 20 mass % is due to the increase in humidity of biscuit semi-finished products , due to increased moisture retention capacity starch ECF.

Using ECF allows for obtaining semi-finished biscuit products even with the complete replacement of WF of the highest grade with quality indicators almost at the level of the control sample. Obviously, this is due to the changes that occur during extrusion: 70% of ECF consists of carbohydrates, of which 85% is starch damaged by grinding flour granules, which under the influence of heat and moisture are partially gelatinized. Under the influence of shear deformation, whole and gelatinized starch granules decompose into separate polymers (amylose and amylopectin), some of which are partially dextrinized under the influence of heat and shear deformation. In the process of hot extrusion at high processing temperatures, low humidity and significant mechanical action, there are, first of all, processes of mechanical destruction of starch granules and polymers, and starch gelatinization is limited [133, 134]. Revealing the properties of the hydrocolloid, ECF starch has a stabilizing effect, increasing the stability of the biscuit cake foam and improving its physical properties, increases the moisture-binding capacity of the dough, improving the volume output and structural and mechanical properties of biscuit semi-finished products. Thus, using ECF helps improve the technological performance of biscuit semi-finished products, improve porosity, increase output, and extend the finished product's shelf life compared to traditional products.

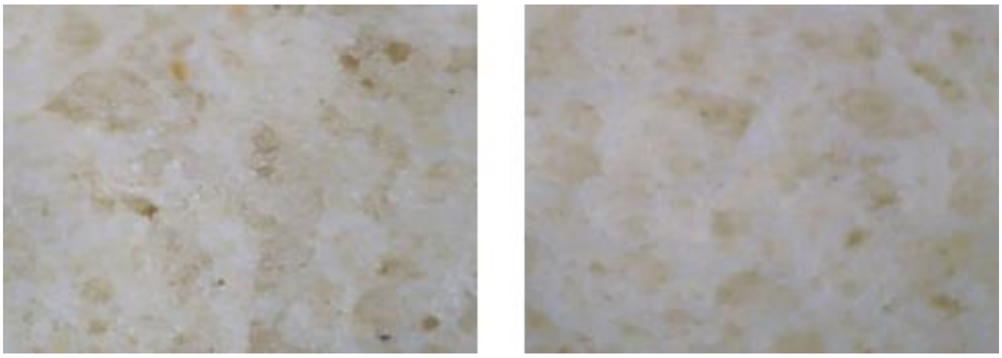
3.2. Mathematical modeling of the ratio of prescription components of gluten-free biscuit semi-finished products based on ECF

Based on the analysis of the obtained experimental data (Section 2), it can be shown that using ECF helps stabilize the foam system of biscuit cake and increases its water absorption capacity. Its use will solve the problem of stabilizing the structure, increase the output of finished products and expand the range of WF by creating a gluten-free biscuit semi-finished products.

The conducted complex of researches allowed to scientifically substantiate the technology and recipes of biscuit semi-finished products with the use of ECF and to offer their range. The results showed that the optimal amount of ECF is 20 mass % From the total flour content. It is also advisable to replace 100% by weight of high-grade WF with ECF, provided the optimal ratio of biscuit semi-finished product components.

During the experimental work characteristics of biscuit semi-finished products were determined and statistical analysis was performed. Measurements of porosity of biscuit semi-finished products samples (Fig. 3.4) were performed by measuring effective pore diameters on biscuit cross sections (Fig. 3.5) by visualizing the biscuit structure and processing the measurement results using MathCAD-14 using the method [135, 136]. This allows qualitatively and quantitatively assess the material's structural characteristics with a slight error of testing, which will further ensure the selection of matrix ingredients with optimal performance characteristics.

After processing the research results, a matrix of color gradient values was obtained on the fragments of the photographed images of the material (biscuit semi-finished products). The presence of zones of high gradient values around inhomogeneities (inclusions, pores, areas with variable humidity) was observed on all selected fragments. In addition, in the matrix around air inclusions or particle inclusions, these zones were also observed to be slightly smaller in maximum gradient values compared to trivial materials. This indicates that in this case structural changes occur to a lesser extent.



a) b)

Figure 3.4 – Photos of thin slices of biscuit semi-finished products:
a) control; b) «Gluten-free»

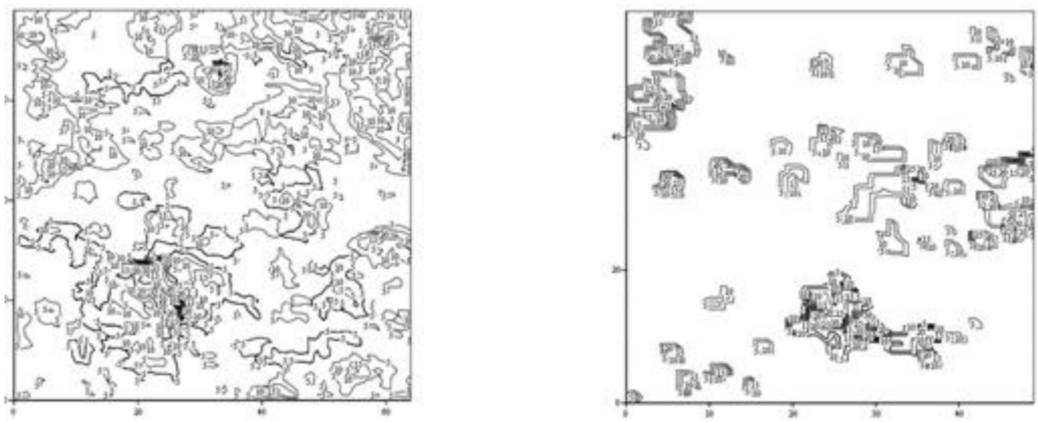


Figure 3.5 – Visualization of pores by applying the brightness gradient operator of the sample image and digitization of brightness level lines (scale 1: 1):
a) control; b) «Gluten-free»

This phenomenon can be explained by the formation of supramolecular structures in the form of globular aggregates of macromolecules, both around-air inclusions and in the volume of the matrix, which indicates the formation of a heterogeneous structure.

A full-factor experiment was performed to determine the rational ratio of components – sugar content, egg melange. Within the two-factor model, the method of modeling the moisture content, density, porosity and baking from the content of egg melange, sugar and ECF was used. By the number of factors more than two full-factor experiment becomes unattractive, irrational in the number of technological experiments.

In order not to complicate the mathematical model, three two-factor experiments 23 were performed with variation of the content of egg melange (x1,%), sugar (x2,%) at fixed values of flour (%). The operator of the MathCAD extremum estimation program for the function G (E, C, B) gives the optimality result: max (g) = 6.47 (kg/m3), max (v) = 98%, min (u) = 10%, max (p) = 81.1%. Mathematical processing of the results of experimental studies allowed to obtain the regression equation and the response surface (Figs. 3.6, 3.7).

According to the obtained regression equations, the rational content of recipe components is determined, which provides optimal density values. The program for calculating the parameters of the quadratic model of the dependence of density on the content of ingredients provides an opportunity to obtain a polynomial formula for further research:

$$G(E,C,B) = 102{,}25 \cdot C - 87{,}66 \cdot C \cdot B - 165{,}12 \cdot C^2 - 143{,}25 \cdot B^2 + 145{,}88 \cdot B - 37{,}08$$

Similarly to the program results for calculating the parameters of the quadratic model of density versus ingredient content using MathCAD-14, we obtain analytical expressions showing the dependences of baking, porosity, and moisture content on the parameters of egg products, sugar, and flour.

The study of the model makes it possible to state that the optimum density of the biscuit semi-finished products is achieved for the parameters (E, C, B) = (0.5; 0.24; 0.24) with a high level of accuracy – 1.4%.

According to the results of optimization, biscuit semi-finished products using ECF has the following intervals of optimization parameters (Fig. 3.6): 100 mass % – replacement of wheat flour on ECF with a quantitative ratio of prescription components «eggs: sugar: flourя» 2.1: 1: 1, 02, at x1 = 51%, x2 = 24.4%, and the content of ECF 24.6% with an accuracy of 0.4%, 0.14% and 0.12%, respectively, the best indicators of baking, porosity, density are achieved dough and moisture content. Mathematical processing of the research results allowed to optimize the recipe of biscuit semi-finished products, which was named «Gluten-free».

$$V(E,C,B) = 13{,}06 \cdot E + 0{,}61 \cdot C + 2{,}31 \cdot B - 13{,}11 \cdot E^2 - 1{,}31 \cdot C^2 - 4{,}97 \cdot B^2 - 2{,}61;$$

$$U(E,C,B) = -3{,}38 \cdot E - 2{,}88 \cdot C + 3{,}38 \cdot E^2 + 6{,}27 \cdot C^2 + 11{,}18;$$

$$P(E,C,B) = 625 \cdot E - 625 \cdot E^2 - 2393 \cdot C^2 + 1100{,}78 \cdot C - 2339{,}0 \cdot B^2 + 1263{,}06 \cdot B - 371{,}85;$$

3.3. Investigation of moisture bonding forms in biscuit semi-finished products using ECF

In order to carry out the hydrolytic processes that take place in the dough cake and baked semi-finished products, it must contain free moisture, which enters into chemical reactions without restrictions. In our opinion, there are only a few studies on the composition of free and bound moisture and the role of moisture bonding in terms of product preservation in relation to biscuit semi-finished products.

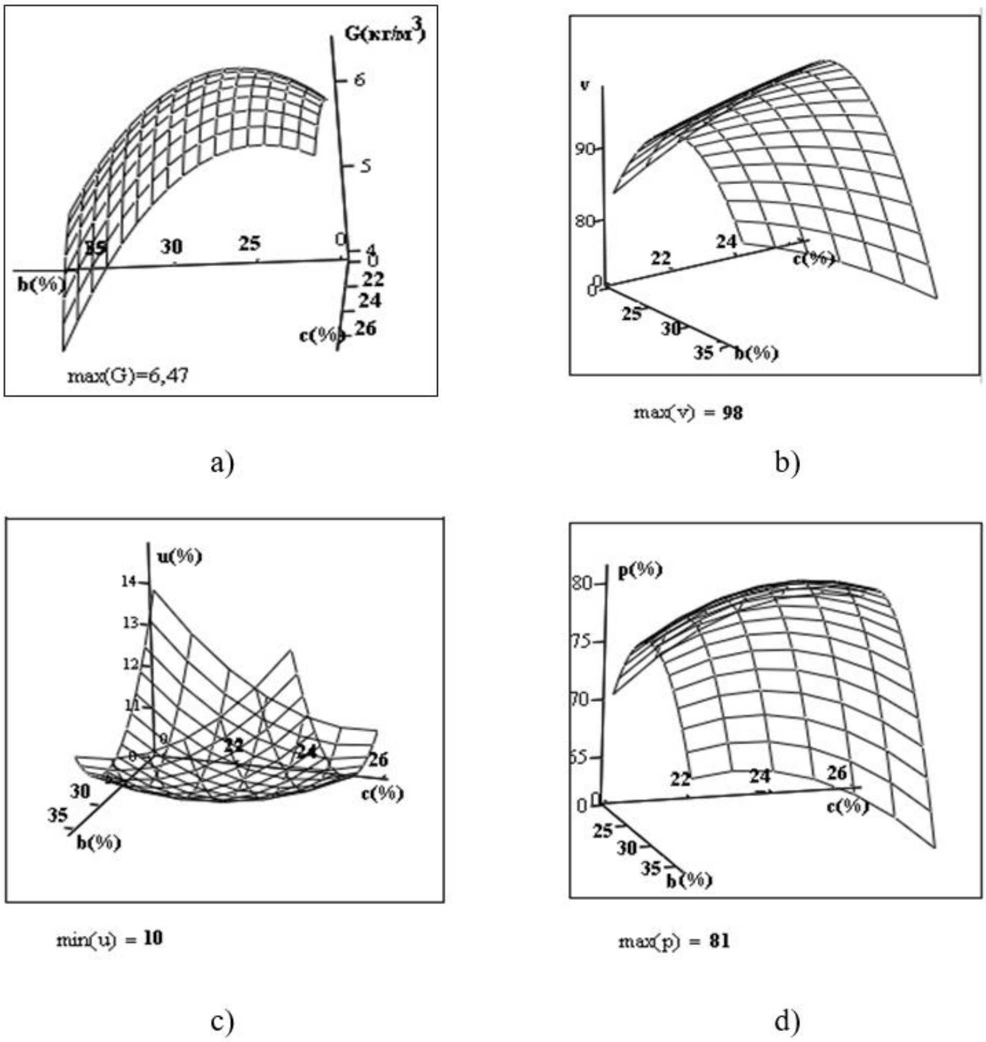


Figure 3.6 – Surfaces of the dependence of density (a), moisture content (b), baking (c) and porosity (d) on the content of eggs products and sugar biscuit dough

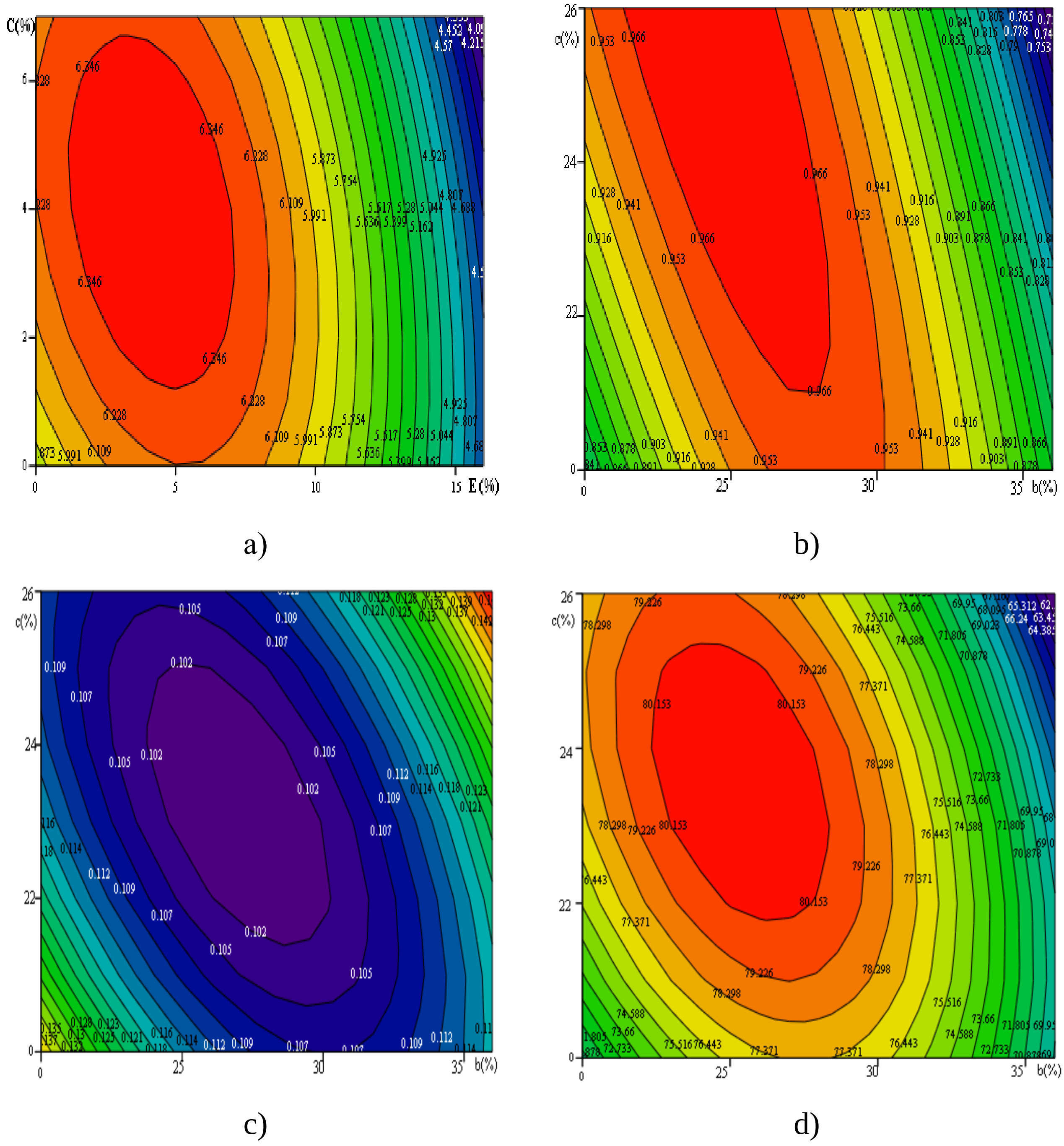


Figure 3.7 – Lines of density level (a), moisture content (b), baking (c) and porosity (d) of biscuit dough in relation to the parameters of eggs and sugar content

The kinetic characteristics influence the final quality of flour confectionery products in the process of their manufacture, namely the removal of moisture during heat treatment in the zone of high temperatures. In the process of baking, the dough is subjected to heat treatment. As a result, it acquires qualitatively new characteristics that form organoleptic and structural-mechanical parameters, nutritional and biological value, creating appropriate conditions for transportation and storage. At this stage, the biscuit dough fixes the foam-like structure, due to denaturation of proteins, gelatinization of starch, as well as the expansion of the bubbles of the air phase, their subsequent rupture and merger. In addition, there is a loss of moisture from the product's surface due to evaporation, followed by migration of moisture to the surface and release into the atmosphere of the furnace.

The formation of the porous structure of the biscuit occurs mainly in the first third of the baking period, and its consolidation and fixation – at the last stage of baking and during cooling and aging. Obtaining a homogeneous structure with rounded pores depends on the baking parameters. The temperature and duration of baking affect the process of expansion of the dispersed air phase and the formation of the foam structure of the finished product, which is fixed during gelatinization of starch matrix, denaturation of protein and curing due to moisture evaporation [137, 138].

The study of the form of connection of moisture with the prescription components in biscuit semi-finished products and their change in the process of heat treatment provides an opportunity to adjust the baking parameters and quality indicators of the finished product as a whole. Studies of changes in the state of moisture in food during heat treatment were carried out on the basis of kinetic parameters of endothermic processes that occur with changes in mass using thermogravimetry (TG) and differential thermal analysis (DTA) on a derivatograph. These methods are based on the assumption that under conditions of constant heating rate, the value of the degree of mass change or heat absorption by the system at the beginning of the fixed zone and the maximum development of the process are proportional to the conversion rate constant for each temperature value [139–142]. Therefore, studying the forms of moisture bonding and their influence on the formation of the biscuit semi-finished products structure using ECF using the method of differential thermal analysis is crucial.

Both the quantitative ratio of free and bound moisture and the distribution of bound water between the biopolymers of the product play an essential role in the study of the properties of biscuit semi-finished products and its ability to retain freshness. The main components that bind water in flour products are starch, protein and pentosans. The total amount of water absorbed by the dough is distributed as follows: 31.1% is sorbed by protein, mainly osmotically, 45.5% by starch – adsorption and 23.4% – by pentosans [143].

Derivatograms obtained during the analysis of control and test samples of biscuit semi-finished products on the basis of flour mixtures with ECF in the ratio to WF 20:80 mass %, And 0 : 100 mass % after 6 hours of aging, are given in annex A. On derivatograms peaks of the DTG curve indicate the processes that occur with the loss of mass of the sample. It can be assumed that the mass decrease occurs due to moisture loss from the experimental systems of biscuit semi-finished products. Removing moisture from all experimental samples takes place in three stages, because the DTG and DTA curves recorded three endoeffects. Analysis of the results of processing derivatives allowed to show some common patterns for all test specimens. The presence of three temperature ranges is characteristic, each of which is associated with the removal of moisture of different types, differing in the strength of the connection with the components.

At the first stage in the temperature range of 40… 100 °C there is an almost linear change in the mass of the sample and a slight loss of moisture up to 6%. This effect is common to all samples. Apparently, at this stage, the removal of free moisture, which is in the large capillaries and cells of the biscuit semi-finished products. In the temperature range of 140… 205 °C, the intensity of water removal from the dough increases, and the rate of change of temperature of the sample slow down. It can be assumed that in this interval water is removed, which is bound by the adsorption centers of polysaccharides and hydroxyl groups of proteins. Differences in the strength of the connection with such centers is manifested in the asymmetry of the peak on the DTA curves and the presence of several peaks. The most pronounced division of the endothermic peak into several partial peaks occurs for the sample with a content of ECF 100 mass %.

With a further increase in temperature is the removal of a significant amount of moisture: up to 22.8% for the control sample at a temperature of 295 °C, for a sample containing ECF 20 mass % Removed up to 25.6% moisture at a temperature of 303 °C, for a sample with ECF content of 100 mass % removes up to 27.2% moisture at a temperature of 308 °C. Data on the content of free and bound moisture in the experimental samples of biscuit semi-finished products in the process of heat treatment are given in table 3.5.

Table 3.5 – The content of released moisture in the biscuit semi-finished products

№	Sample № 1 Control – 100 mass % WF			Sample № 2 ECF:WF – 20:80 mass %			Sample № 3 ECF:WF – 100:0 mass %		
	Temperature maximum, °C	The amount of moisture released from the sample, mg	Moisture content to total moisture, %	Temperature maximum, °C	The amount of moisture released from the sample, mg	Moisture content to total moisture, %	Temperature maximum, °C	The amount of moisture released from the sample, mg	Moisture content to total moisture, %
Free moisture									
1	77	30	6	75	26	6	88	30	6
	83	36	7	100	34	8	100	42	9
	100	42	8						
Bound moisture									
2	140	44	9	145	38	9	150	48	10
	198	60	12	198	58	14	205	60	13
3	227	74	15	230	72	15	240	76	16
	268	100	20	275	92	22	280	100	20
	295	114	23	303	110	26	308	128	26

To obtain data on the mechanism of removal of moisture on the TG curves, we calculated the degree of change in the mass α of the biscuit semi-finished products of the control sample and using ECF (Fig. 3.8) and built the dependence | -lgα | from the value of the return temperature 1000/K.

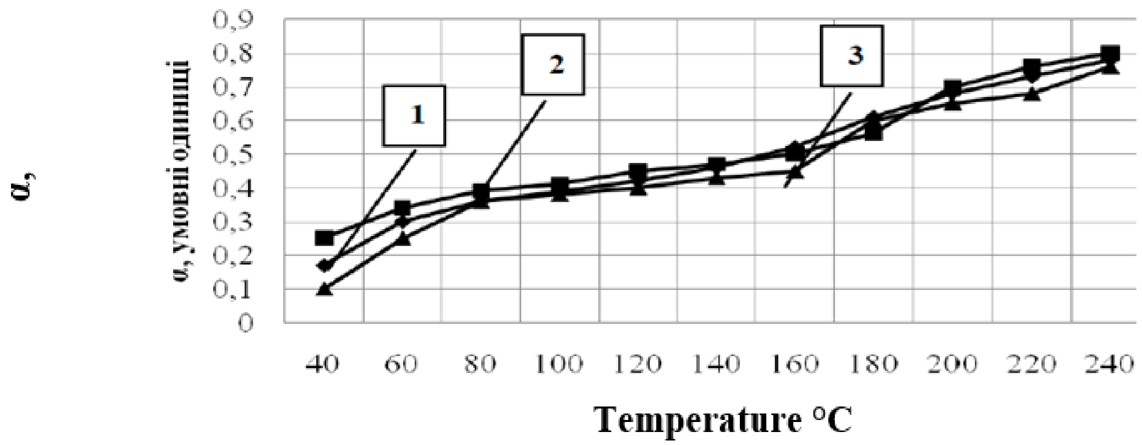


Figure 3.8 – Change of sample weight from biscuit semi-finished products temperature:

1 – (control); 2 – ECF: WF – 20:80 mass %; 3 – ECF: WF – 100 mass %

The rate of change of mass corresponding to the process was used to obtain the dependence of the change in mass on temperature. For this purpose, a change in the mass Δ m1 of the sample corresponding to the amount of moisture that evaporated at this temperature was found on the TG curve at constant temperature intervals at 20 °C.

The degree of change in mass α was calculated as Δ m1 with an interval of 20 °C to the total amount of water contained in the biscuit semi-finished products, removed at the end of the dehydration process.

The obtained curves in α-t coordinates (Fig. 3.8) characterize different forms of interaction of water and dry matter in biscuit semi-finished product and as a result of these interactions the similarity of the curves in the rate of water release during heat treatment. The curves of the dependence of the change in the mass of biscuit semi-finished products on temperature allow to study the kinetics of unequal forms of moisture bonding and reflect almost the same rate of dehydration.

In the first stage at temperatures of 40… 100 °C (Fig. 3.9, segment AB) is the removal of free moisture or mechanically bound, which has a low binding energy with the components of the product. First, water is released, which is interconnected by hydrogen bonds.

The desorption of capillary water is characterized by lower values of activation energy compared to the water released in the second stage of heat treatment (segment VS).

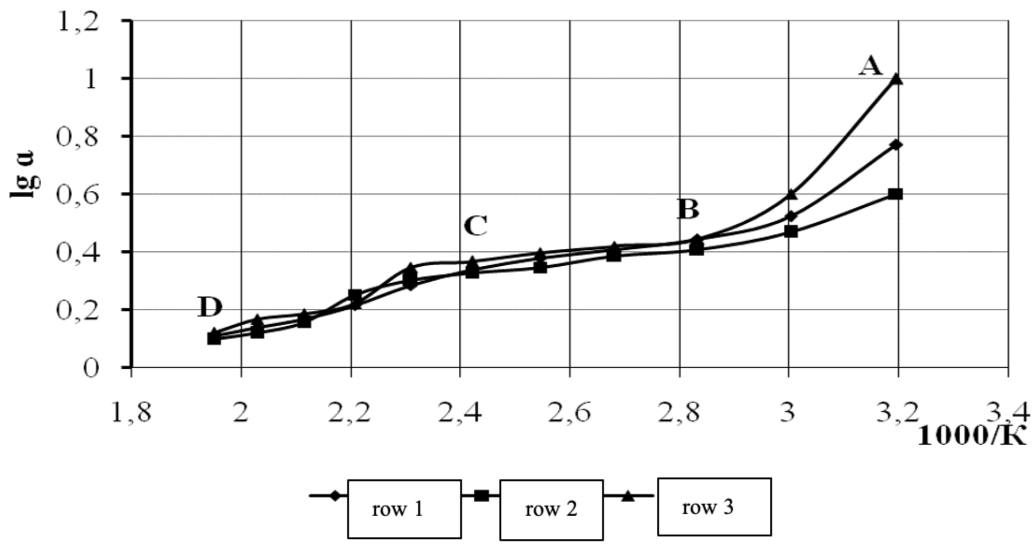


Figure 3.9 – Dependence of the logarithm of the degree of mass change on the biscuit semi-finished products temperature:

1 – (control); 2 – ECF: WF – 20:80 mass %; 3 – ECF: WF – 100: 0 mass %

The second stage (at temperatures of 100… 160 °C) releases osmotically bound moisture, which can be retained in the cells of protein molecules. This type of moisture is released during the deployment of polypeptide chains as a result of disruption of hydrophobic interactions of proteins with water, as well as the possible removal of weakly bound adsorption moisture. In the third stage (segment CD) at temperatures of 160… 240 °C it can be assumed that the release of strongly bound adsorption chemically bound moisture takes place.

The obtained dependences show the peculiarities related to the influence of flour mixtures on the state of moisture in biscuit semi-finished products. The use of ECF causes a redistribution of moisture bonding forms, reduces the amount of free and easily bound moisture and increases the amount of strongly bound moisture. With the increase in the amount of ECF to 100 mass %, This dependence is clearly traced, and the amount of strongly bound moisture increases, which corresponds to the range from 227… 308 °C.

The presence of more bound moisture in the system will help improve the technological characteristics of biscuit semi-finished products during its baking and storage. It is believed that in the pulp of biscuit semi-finished products moisture is in several qualitatively different states, so to consider changes in its properties during storage, it is necessary to take into account the role of moisture in it [144].

The process of hardening the biscuit semi-finished products is associated with changes in the water-starch and water-protein systems. And it is in the change of moisture during storage of products that thermodynamically bound water molecules and moisture, which is distributed in the intermolecular space of denatured protein and partially gelatinized starch, and is osmotically bound, play a significant role. Therefore, the thermogravimetric method was used to study the mechanism of changes in the state of water in the biscuit semi-finished products during storage [145].

The study of the peculiarities of biscuit semi-finished products moisture release using ECF, analysis of the obtained patterns and determining the trend of ECF influence on the dynamics of changes in the quality of the finished product during storage using thermogravimetric analysis requires detailed study. This method is based on the assumption that under conditions of constant heating rate, the value of the degree of change in mass or heat absorption by the system at the beginning of the fixed zone and the maximum development of the process are proportional to the conversion rate constant for each temperature value [146].

The experimental data described above indicate that using ECF in biscuit semi-finished products technology can increase the proportion of bound moisture [147]. It is obvious that such biscuits will keep fresh longer.

In this regard, the study aimed to study the effect of ECF on the forms of moisture bonding during the storage of biscuit semi-finished products using thermogravimetric analysis.

The following biscuit semi-finished products were selected as the object of research:

«Basic», made according to standard recipe and technology (control);

«Sun» using ECF in the ratio of biscuit semi-finished products in the ratio of ECF: WF – 20:80 mass %;

«Gluten-free» with a complete replacement of WF on ECF.

The studies were performed after 24, 48 and 72 · 602 s after baking the biscuit semi-finished products and storage in a polymer container at a temperature of (20 ± 2) °C and relative humidity (75 ± 2)%. Derivatograms obtained during the analysis of the control sample, biscuit semi-finished products «Sun» and «Gluten-free», after 24 and 48 and 72 · 60^2 s storage, are given in Annex A.

The peaks of the DTG curve indicate the processes that occur with the loss of mass of the sample. It can be assumed that during heating the weight loss occurs as a result of moisture loss from the experimental systems of biscuit semi-finished products, then the process of removing moisture from all experimental samples occurs in three stages, because the DTG and DTA curves recorded three endoeffects. Analysis of the results of derivatogram processing indicates some common patterns for all biscuit semi-finished products samples.

A characteristic feature is the presence of three temperature ranges, each of which is associated with the release of moisture of different types, differing in the strength of the connection with the components and the amount of moisture released. During the thermogravimetric analysis in the temperature range 40… 100 °C for samples after 24 · 60^2 s of their storage there is an almost linear change of mass of the sample and moisture loss is from 6% to 11%. This effect is common to all samples. Apparently, at this stage, the free moisture that is in the large capillaries and cells of the biscuit semi-finished products and the moisture released as a result of denaturation of the protein and the destruction of the bonds of its molecules with water molecules.

In the temperature range 140… 205 °C, in all samples the intensity of water removal from the biscuit cake increases, and the rate of change of the sample temperature slows down and remains relatively constant. During this interval, water is removed, which is bound by the adsorption centers of polysaccharides and hydroxyl groups of proteins and moisture, which is equally bound to other components of the biscuit semi-finished products. Differences in the strength of the connection with such centers is manifested in the asymmetry of the peak on the DTA curves and the presence of several peaks. The weight loss in these areas for samples «Sun» is up to (33.8… 38.0)%, for samples «Gluten-free» is up to (32.0… 37.5)%, and for control samples is up to (42, 0… 54.0)% regardless of the duration of storage.

In biscuit semi-finished products samples stored for $24 \cdot 60^2$ s, with a subsequent increase in temperature, during the thermal analysis is the removal of significant amounts of moisture: up to 23% for the control sample at 295 °C, for the sample «Sun» – up to 26% at temperature 303 °C, for the sample «Gluten-free» – up to 27%, at a temperature of 308 °C.

Data on the content of free and bound moisture in the process of heat treatment in experimental samples of biscuit semi-finished products for different durations of its storage are given in table. 3.6. The analysis of the obtained data revealed that in biscuit semi-finished products samples after $48 \cdot 60^2$ s storage, the most intensive release of moisture occurs for the control sample at a temperature of 272 °C – up to 24%, for the sample «Sun» removes up to 32% moisture at a temperature – 303 °C, for the sample «Gluten-free» up to 33% of moisture is removed at a temperature of 312 °C.

The analysis of the obtained results showed that during storage of biscuits for 48 · 602, the moisture loss of the control sample was 16%, while in the semi-finished products «Sun» the amount of moisture decreased by 10%, and «Gluten-free» – by 6% [148].

The ability to absorb moisture is characteristic of starch – the main component of ECF, which is a strong and at the same time, labile compound.

Table 3.6 – Moisture content in biscuit semi-finished products after storage

№	Control			«Sun»			«Gluten-free»		
	Temperature maximum, oC	The amount of moisture released from the sample, mg	Moisture content to total moisture, %	Temperature maximum, oC	The amount of moisture released from the sample, mg	Moisture content to total moisture, %	Temperature maximum, oC	The amount of moisture released from the sample, mg	Moisture content to total moisture, %
During 24·602 c									
Free moisture									
1	77±2	30±0,5	9±0,5	79±2	35±0,5	6±0,5	88±2	30±0,5	7±0,5
	83±2	36±0,5	10±0,5	85±2	20±0,5	5±0,5	100±2	42±0,5	9±0,5
Bound moisture									
2	140±2	44±0,5	9±0,5	145±2	38±0,5	9±0,5	150±2	48±0,5	10±0,5
	198±2	60±0,5	12±0,5	198±2	58±0,5	14±0,5	205±2	60±0,5	13±0,5
	227±2	74±0,5	15±0,5	230±2	72±0,5	15±0,5	240±2	76±0,5	16±0,5
3	268±2	100±0,5	20±0,5	275±2	115±0,5	23±0,5	280±2	95±0,5	19±0,5
	295±2	114±0,5	23±0,5	308±2	140±0,5	26±0,5	303±2	135±0,5	26±0,5
During 48·602 c									
Free moisture									
1	72±2	80±0,5	16±0,5	75±2	50±0,5	10±0,5	82±2	40±0,5	8±0,5
Bound moisture									
2	143±1	90±0,5	18±0,5	150±2	85±0,5	17±0,5	158±2	80±0,5	15±0,5
	200±2	100±0,5	20±0,5	197±2	75±0,5	16±0,5	197±2	80±0,5	16±0,5
3	229±2	110±0,5	22±0,5	230±2	125±0,5	25±0,5	230±2	140±0,5	28±0,5
	272±2	120±0,5	24±0,5	308±2	185±0,5	32±0,5	312±2	160±0,5	33±0,5
During 72·602 c									
Free moisture									
1	79±2	55±0,5	11±0,5	82±2	45±0,5	9±0,5	80±2	30±0,5	6±0,5
Bound moisture									
2	148±2	65±0,5	13±0,5	150±2	60±0,5	12±0,5	176±2	50±0,5	10±0,5
	204±2	80±0,5	16±0,5	200±2	80±0,5	16±0,5	205±2	85±0,5	17±0,5
	233±2	95±0,5	19±0,5	230±2	90±0,5	18±0,5	230±2	95±0,5	19±0,5
3	277±2	100±0,5	20±0,5	282±2	100±0,5	20±0,5	280±2	110±0,5	22±0,5
	305±2	120±0,5	21±0,5	310±2	125±0,5	25±0,5	320±2	130±0,5	26±0,5

Since ECF starch changes its structure under the action of extrusion, it is quite possible to increase the adsorption capacity of starch, and, as a consequence, increase the amount of strongly bound moisture in the biscuit semi-finished products. According to the data obtained after $72 \cdot 60^2$ s, the amount of lost moisture in each test sample became approximately the same asin the control sample after the first $48 \cdot 60^2$ s storage. It should be noted that for $72 \cdot 60^2$ s of storage, ECF products lose almost 25% less moisture compared to the control.

The rest of the moisture, due to the higher partial pressure compared to the partial pressure of water vapor in the capillary space, penetrates the microcapillaries and occupies vacancies in the structural elements of biopolymers. According to research results, the content of bound moisture in the micropores increases in the range of 6… 9%.

The filling of micropores with free moisture and its transition to a bound state can be explained by the emergence of hydrogen bonds between water molecules and components of the biscuit semi-finished products. There are several options for moisture migration, particularly by a chain mechanism with the formation of hydrogen bridges, which are firmly held in the capillary space [149]. In addition, water with increased mobility may be retained in the capillaries without forming any water bridges. Such moisture, in the first place, is removed by thermographic analysis in the form of free moisture.

The results of the study are given in table. 3.6, indicate a decrease in the proportion of moisture that has the highest molecular mobility in the biscuit semi-finished products after 72 · 602 s of storage. With respect to osmotically bound moisture (t = 90… 150 °C), there is a tendency to reduce its content during storage of the biscuit. In the studied flour products in the process of hardening, partially gelatinized wheat flour starch is capable of rapid «aging», and ECF is able to retain moisture, which is lost by amylose and amylopectin molecules during starch retrogradation.

For the experimental samples, the content of adsorption-bound moisture (t = 150… 310 °C) after $72 \cdot 60^2$ s of biscuit storage remains increased by an average of 2… 3% compared to the control sample. It is obvious that due to the use of ECF there is some delay in the processes of molecular movement of moisture inside the product. It is known that during the storage of flour products, the degree of mobility of free moisture in it increases, and bound, strongly associated with biopolymers, on the contrary, decreases.

In biscuit semi-finished products made by traditional technology, water molecules pass along the chains of starch polymers, due to the increased mobility of moisture during storage of the product, which contributes to the formation of additional bonds between them and the pulp becomes structurally rigid. For biscuit semi-finished products with the use of ECF moisture mobility is reduced, which will extend the shelf life of its freshness. Obviously, the addition of ECF helps to reduce the rate of evaporation of moisture in the test samples, which is a very important technological factor during storage of biscuit semi-finished products. Changes in the rate of moisture evaporation in biscuit semi-finished products during storage of control and test samples are given in the table 3.7.

Table 3.7 – Changes in the speed of loss of moisture biscuit semi-finished products during storage

Semi-finished products	**Moisture evaporation speed, mg/degrees**			
	75…120 °C	**120…210 °C**	**210…280 °C**	**280…400 °C**
Duration of storage 24×60^2 s				
Control	41,5±0,8	3,0±0,06	2,0±0,05	3,8±0,07
Sun	69,0±1,3	2,8±0,05	4,2±0,08	4,5±0,08
Gluten-free	38,0±0,7	3,0±0,06	3,4±0,06	4,4±0,08
Duration of storage 48×60^2 s				
Control	51,1±0,9	5,5±0,11	4,8±0,09	4,4±0,08
Sun	66,0±1,3	4,0±0,07	5,4±0,1	6,0±0,12
Gluten-free	36,0±0,7	3.6±0,06	6,0±0,12	6,4±0,13
Duration of storage 72×60^2 s				
Control	69,6±1,3	4,1±0,08	3,8±0,07	3,9±0,08
Sun	55,0±1,1	4,0±0,08	3,7±0,07	4,0±0,08
Gluten-free	37,0±0,7	3,5±0,06	4,0±0,08	4,0±0,08

It should be noted that the dependences TG, DTG, DTA (Appendix A) of all studied objects are typical, but differ in quantitative values. On derivatograms, depending on the temperature interval of heating, the TG curve can be divided into areas where the most intense changes in the components of the studied food systems. That is why in the table. 3.7 shows the changes in the moisture evaporation rate in the biscuit semi-finished products during a certain period of storage in these temperature ranges. According to the results of the study, it was found that biscuit semi-finished products samples are characterized by a high rate of reduction of the weight of the semi-finished products, both in the control and with the addition of ECF, regardless of the duration of its storage. However, in control, after 24 · 602 s, storage speed is 8.4% higher than in the sample «Gluten-free», and after 48 · 602 s it increases by 30% and after 72 · 602 s it increases by another 47%. In the samples of biscuit semi-finished products «Sun» there was no significant decrease in the moisture evaporation rate, which can be due only to the partial replacement of biscuit semi-finished products in its composition on ECF (up to 20 mass %).

Based on the results obtained, it can be argued that the use of ECF, which indicates the properties of the hydrocolloid and acts as a moisture-retaining agent, is appropriate in the production of biscuit semi-finished products. Due to its hygroscopicity, ECF binds moisture in the freshly prepared product and significantly slows down its removal during baking and storage of baked semi-finished products.

Analysis of derivatograms indicates the presence of temperature ranges, each of which is associated with the removal of moisture of different types, differing in the strength of the connection with the constituent components. As the amount of ECF increases, the amount of strongly bound moisture increases, which is removed from the system in the range of 227… 308 °C, and contributes to the improvement of technological characteristics of biscuit semi-finished products during its storage.

After $72 \cdot 60^2$ s, the amount of lost moisture in each test sample became approximately the same as in the control sample after the first $48 \cdot 60^2$ s of storage. It should be noted that for $72 \cdot 60^2$ s of storage, ECF products lose almost 25% less moisture compared to the control.

Thus, using ECF for biscuit semi-finished products reduces the intensity of moisture in this system, leading to an increase in the amount of bound moisture, which is a positive technological factor that prolongs the shelf life of biscuits and allows to predict their shelf life.

3.4. Development of biscuit semi-finished products technology using ECF

The complex of theoretical and experimental researches allowed to develop the technological scheme of biscuit semi-finished products production with the use of ECF.

Applying a systems approach in developing biscuit semi-finished products technology using ECF allows identification of subsystems in the technological system. This approach involves the functional organization of the system, which reflects the set of its functions, the relationship between them and in the structural organization that characterizes the composition of the system. An important feature of the system approach is the simultaneous consideration during the analysis and synthesis of all components of the technological flow both in the middle of the system and in the process of its exchange with the external environment. The criterion for the system's functioning is to obtain products with certain organoleptic, physicochemical and technological parameters. Based on theoretical and experimental research, the biscuit semi-finished products compounding with ECF is developed (tab. 3.8).

Table 3.8 – Formulation of biscuit semi-finished products using ECF

Raw	Dry matter substances, %	Raw material costs of 100 kg biscuit semi-finished products (kg)			
		Sun		Gluten-free	
		in practice	**in dry matter**	**in practice**	**In dry matter**
WF	85,50	26,0	22,23	-	-
ECF	91,0	8,07	7,34	30,58	27,82
Eggs	27,0	57,85	15,62	63,44	17,12
Sugar	99,7	34,71	34,65	30,26	30,16
Total		126,63	79,84	124,28	75,1
Output	79,0	100,0	79,0	100,0	75,00

The technological process of production of biscuit semi-finished products with using ECF consists of the following subsystems: A – «Formation of biscuit semi-finished products using ECF», B1 – «Obtaining egg-sugar mixture», B2 – «Kneading dough», B3 – «Forming dough», B4 – «Baking and cooling», B5 – «Standing», C1 – «Preparation of egg melange», C2 – «Preparation of sugar», C3 – «Preparation of premium wheat flour», C4 – «Preparation of ECF», C – «Preparation of prescription components».

The model of the technological system of biscuit semi-finished products production using ECF is given in table. 3.9. Subsystem C – «Preparation of prescription components-, involves obtaining prescription components based on the specified ratio and processing. The main recipe components for the preparation of biscuit semi-finished products with using ECF are high-grade wheat flour, ECF, eggs, sugar. The ratio of prescription components of biscuit semi-finished products with using ECF «Gluten-free» is substantiated: eggs: white sugar: ECF – 2,1: 1: 1,02; biscuit semi-finished with product using ECF «Sun»: eggs: white sugar: WF and ECF – 2.06: 1.24: 1 [192].

Preparation of the main components of biscuit semi-finished products is carried out within the subsystems C1 – «Preparation of egg melange», C2 – «Preparation of sugar», C3 – «Preparation of premium wheat flour», C4 – «Preparation of ECF».

Table 3.9 – The structure of the basic technological scheme and the purpose of the operation of its components

Subsystem	**Name of the subsystem**	**The purpose of the subsystem**
1	2	3
A	Formation of biscuit semi-finished products using ECF	Obtaining biscuit semi-finished products using ECF with specified organoleptic, physicochemical, structural and mechanical properties, ready for sale in the retail trade network and restaurants
B_1	Obtaining egg-sugar mixture	Obtaining a foam mixture that provides the formation of the required structural and mechanical properties of the semi-finished products
B_2	Kneading the dough	Obtaining biscuit dough with specified structural-mechanical and organoleptic properties
B_3	Dough formation	Obtaining the required shape of biscuit semi-finished products by forming the dough into baking molds
B_4	Baking and cooling	Obtaining biscuit semi-finished products with the desired characteristics due to the implementation of temperature parameters
B_5	Persistence	Obtaining biscuit semi-finished products with the specified characteristics by stabilizing the structure of biscuit semi-finished products using ECF

End of the table 3.9

C	Preparation of prescription components	Preparation of system components in order to form organoleptic parameters, physicochemical, structural and mechanical properties and nutritional value of finished products
C_1	Preparation of egg melange	Unpacking, dosing, sanitation
C_2	Preparation of sugar	Unpacking, screening, magnetic separation, dosing
C_3	Preparation of WF	Dosing, sieving, magnetic separation and mixing with ECF
C_4	Preparation of ECF	Dosing, sieving, magnetic separation and mixing, with WF

The following operations are performed within the C1 subsystem: eggs are inspected with an ovoscope, processed in baths according to a special scheme and released from the shell. Within the C2 subsystem, the sugar is sifted through small sieves with a diameter of 3 mm to remove impurities.

Subsystem B involves whipping the prepared raw materials (subsystems C1; C2) and mixing with flour raw materials (subsystems C3; C4). The beating provides the necessary air saturation of the egg-sugar mixture to obtain a fine-pore finished semi-finished products. The parameters of beating at which uniform saturation is achieved are determined – duration of beating (40 ± 2) 60 s, melange temperature 20… 25 °C, up to increase in volume by 2.5… 3 times. The duration of mixing with flour does not require clear control for biscuit semi-finished products «Sun», because the presence of ECF prevents swelling of wheat flour proteins and tightening of the dough, after which the dough is formed depending on the type of finished semi-finished products.

The duration of mixing ECF for biscuit «Gluten-free» also does not require limiting the time of kneading the dough, as ECF helps to stabilize the foam system of biscuit dough to technological factors and the production of culinary and confectionery products with high quality. The finished biscuit dough is immediately baked in cake tins and on sheets, as it may partially lose its structure during storage. Forms and sheets are covered with paper or greased. Biscuit cake dough is dosed into molds at ¾ their height, because it increases in volume during baking.

Biscuit dough is usually baked at a temperature of 200… 210 °C, but the baking time depends on the thickness, volume and components of the dough. Baking of biscuit semi-finished products using ECF takes place at a temperature t = 190… 200 °C for 45… 50 · 60 s.

In fig. 3.10, 3.11 technological schemes and range of products based on biscuit semi-finished products with using ECF «Gluten-free» and biscuit semi-finished products «Sun» with 20% replacement of wheat flour on ECF.

The range of biscuit dough products made in restaurants according to the technological scheme is presented in Figures 3.10–3.11 and includes not only ready-to-sell desserts, cakes, pastries and rolls, but also a separate biscuit semi-finished products that can be stored for some time. to be sold in the trade network as a separate food product.

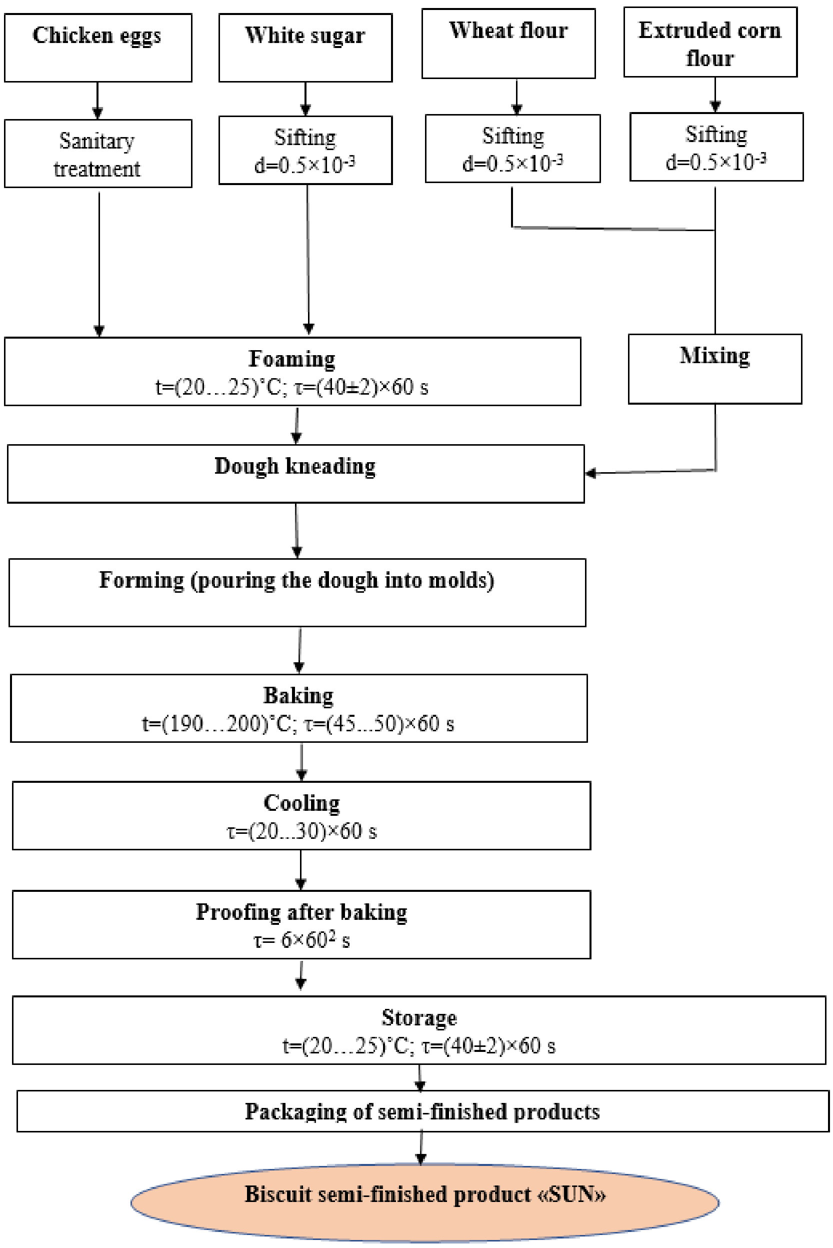


Figure 3.10 – Technological scheme of production of biscuit semi-finished products «Sun» with using ECF

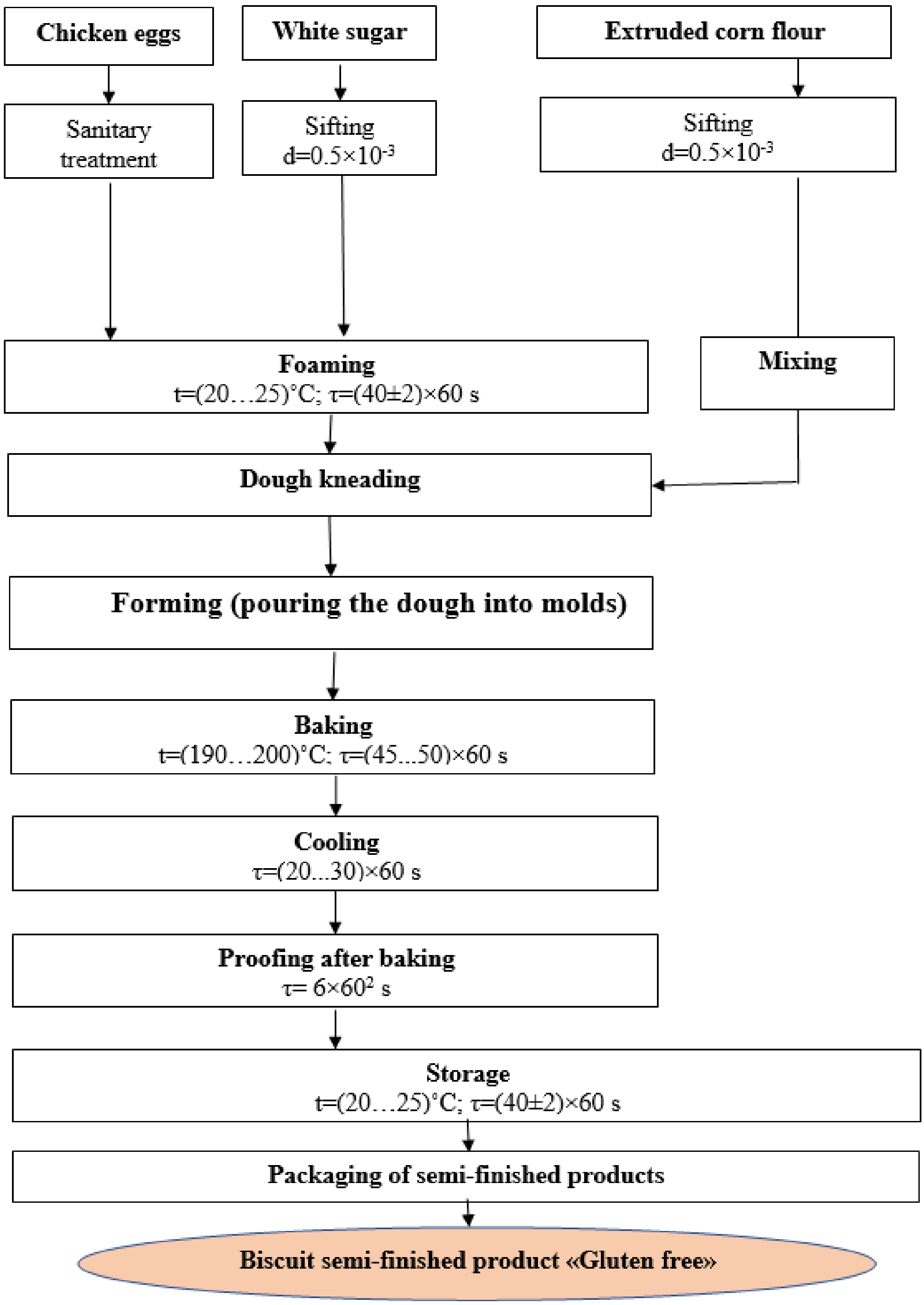


Figure 3.11 – Technological scheme of production of biscuit semi-finished products «Gluten-free» based on ECF

The developed biscuit semi-finished product technology can be recommended for the manufacture of a wide range of biscuit products (cakes, pastries, rolls, cake pops and cake balls). Features of the technology of semi-finished products «Gluten-free» is that during cooking does not require impregnation with syrup, semi-finished products «Sun» can be used, in particular, as the so-called «dry biscuit», Savoyard cookies in culinary products.

Indicators of energy value of the developed biscuit semi-finished products are given in table. 3.10.

Table 3.10 – Energy and nutritional value of biscuit semi-finished products «Sun» and «Gluten-free»

Biscuit semi-finished product	Content (per 100 g), %					Energy value of 100 g of product, kcal
	ashes	protein	carbohydrates	lipids	cellulose	
Sun	1,62	11,0	60,0	7,6	0,13	346,8
Gluten-free	1,8	10	52,3	10	0,2	339,2

On the developed technology of biscuit semi-finished products «Sun» and «Gluten-free» developed TU U 10.7-010566330-305: 2014 Biscuit semi-finished product «Sun» and «Gluten-free».

To determine the allowable shelf life, it is important to study the microbiological parameters of biscuit semi-finished products under storage conditions in airtight polymer packaging. The results of microbiological tests of biscuit semi-finished products «Sun» and «Gluten-free» are given in table. 3.11.

Analysis of experimental data shows that the microbiological parameters of biscuit semi-finished products using ECF are within acceptable values, regulated by regulatory documentation.

Organoleptic characteristics of biscuit semi-finished products with the use of ECF are important for the characterization of food products, in addition to technological indicators. The results of organoleptic study of biscuit semi-finished products are given in table. 3.12.

According to the results of tasting, it was found that as the amount of ECF increases, the taste and smell of the finished product does not deteriorate, but on the contrary, there is a pronounced taste of ECF.

For quantify the quality indicators of biscuit semi-finished products, we used the principles of qualimetry, while the assessment of product quality is considered as a multi-stage process consisting of the assessment of individual indicators, properties and comprehensive assessment of quality in general [150].

Table 3.11 – Microbiological parameters of biscuit semi-finished products with ECF

Duration of storage	Microbiological indicators					
	Number of mesophilic aerobic and facultative anaerobic microorganisms, CFU/g, no more	Bacteria of the Escherichia coli group, mass of product (g), which is not allowed	S. aureus, mass of product (g), which is not allowed	Bacteria of the genus Salmonella, mass of product (g), which is not allowed	Yeast, CFU/g, no more	Mold, CFU/g, no more
Permissible level	1×10^4	1,0	0,1	25	50	50
Actual content for storage (days) of biscuit semi-finished products «Sun»						
0	1×10^1	not found	not found	not found	not found	not found
10	3×10^1	not found	not found	not found	not found	not found
20	1×10^2	not found	not found	not found	not found	not found
30	6×10^2	not found	not found	not found	not found	not found
Actual content for storage (days) of biscuit semi-finished products «Gluten-free»						
0	1×10^1	not found	not found	not found	not found	not found
10	3×10^1	not found	not found	not found	not found	not found
20	1×10^2	not found	not found	not found	not found	not found
30	6×10^2	not found	not found	not found	not found	not found

Table 3.12 – Organoleptic parameters of biscuit semi-finished products using ECF

Index	Control	Biscuit cake semi-finished products	
		Sun	Gluten-free
Surface	The upper crust is smooth, thin, brown	The upper crust is thin smooth brown	The upper crust is thin, rough, dark brown
Color	Cream color	Yellow	Dark yellow
The appearance of the pulp in section	Medium-porous, elastic, without traces of misalignment, retains its shape after aging	Finely porous elastic without traces of misalignment, retains its shape after aging	Medium-porous, elastic, without traces of impermeability, somewhat loses shape after aging
Taste and smell	Sweet with a pronounced taste and aroma of eggs	Sweet taste and light aroma of eggs and ECF	Sweet, distinct aroma and taste of ECF

The resulting product has a pleasant taste, smell and texture. Organoleptic indicators are illustrated in the photos of fig. 3.12.

Control «Sun» «Gluten-free»

Figure 3.12 – Photos of organoleptic parameters of biscuit semi-finished products using ECF

According to the chosen model, the quality of biscuit semi-finished product using ECF is considered as a hierarchical set of properties (Fig. 3.13) that arouse consumer interest. For biscuit semi-finished product – these are organoleptic properties, structural and mechanical properties, shelf life and nutritional value [151].

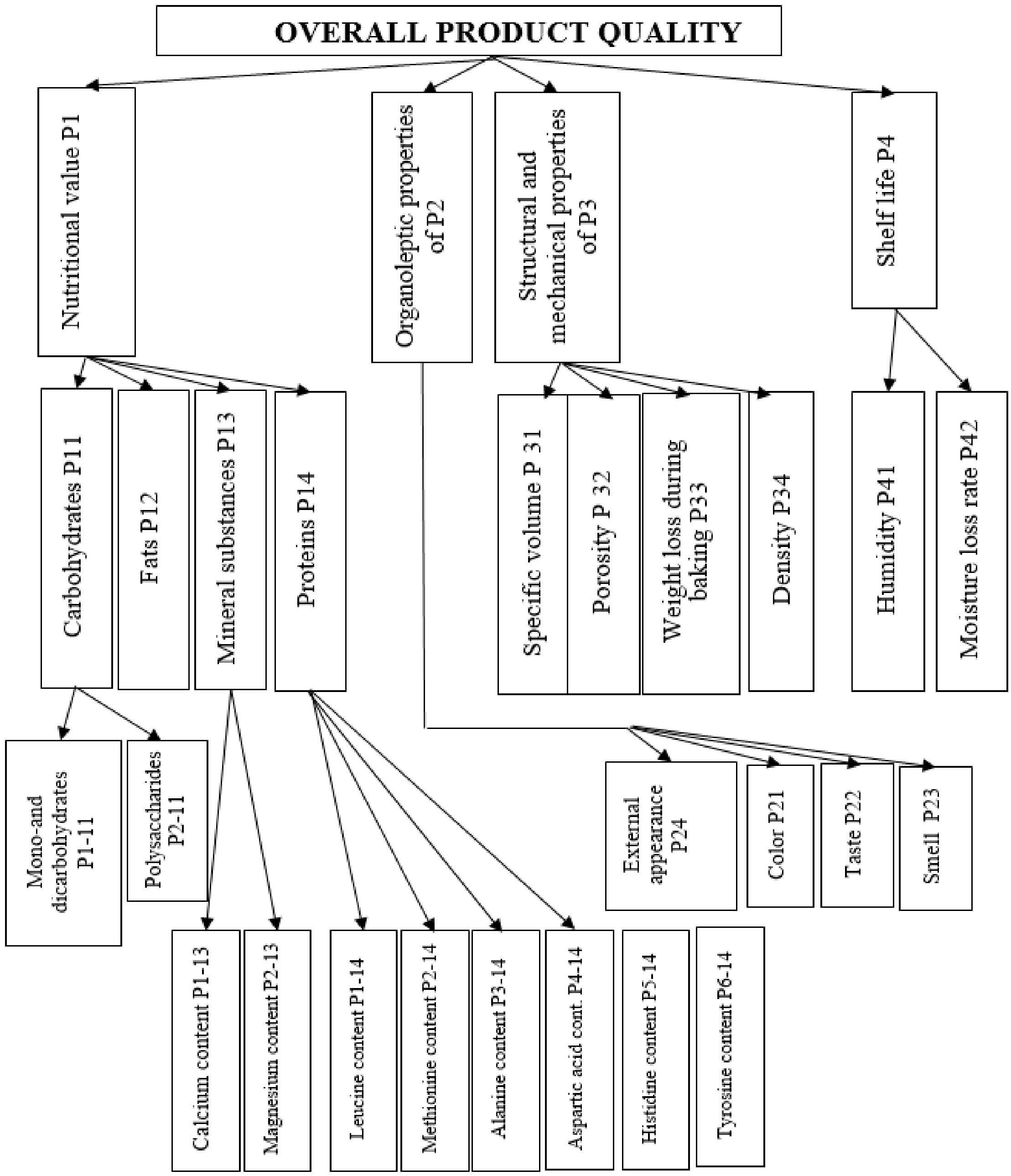


Figure 3.13 – Hierarchical structure of properties required to assess the quality of biscuit semi-finished products

Each property is characterized by its value Pi – a value that quantifies this property, Mi – an indicator that considers this property's weight. The hierarchical tree is constructed so that the properties of the i-th level are determined by the corresponding properties of i + 1 level (where i = 1, 2, 3, etc.).

To assess the level of quality, it is proposed to compare the same type of products with each other or with reference (base) samples. We propose a comparison of the developed biscuit semi-finished products. model with the model of the control sample – BN «Basic». When assessing the quality, according to the chosen method, it is necessary to know not only the parameters of P_i,, which characterize this property, but also the parameters that determine the importance of this indicator. The method of expert evaluation (Delphi method) is used to determine the weights. According to the calculations of experimental data, the value of the indicator that characterizes the significance of the properties that are in the same level, must be constant and equal to a certain constant (in this case, one). Let's choose the weights and basic indicators that characterize the biscuit semi-finished product «Gluten-free»:

M_1=0,30 – nutritional value; M_2=0,35 – organoleptic parameters; M_3=0,15 – structural and mechanical parameters; M_4=0,20 – shelf life;

M_{11}=0,25, P_{11}=0,30 – carbohydrate content; M_{12}=0,20, P_{12}=0,15 – fat content; M_{13}=0,25, P_{13}=0,25 – mineral content; M_{14}=0,35, P_{14}=0,35 – protein content;

$M^1{}_{11}$=0,4, $P^1{}_{11}$=25% – the content of mono- and di-carbohydrates; $M^2{}_{11}$ = 0,6, $P^2{}_{11}$=75% – the content of polycarbohydrates;

$M^1{}_{13}$=0,50, $P^1{}_{13}$=20 mg/100 grams – calcium content; $M^2{}_{13}$=0,50, $P^2{}_{13}$=38 mg/100 grams – magnesium content;

$M^1{}_{14}$=0,2, $P^1{}_{14}$=845 mg/100 grams of protein – leucine content; $M^2{}_{14}$=0,20, $P^2{}_{14}$=133 mg/100 grams of protein – methionine content; $M^3{}_{14}$=0,15, $P^3{}_{14}$=612 mg/100 grams of protein – alanine content; $M^4{}_{14}$=0,15, $P^4{}_{14}$= 579 mg/100 grams of protein – asparagine content. acids; $M^5{}_{14}$=0,15, $P^5{}_{14}$=157 mg/100 grams of protein – histidine content; $M^6{}_{14}$=0,15, $P^6{}_{14}$=308 mg/100 grams – tyrosine content;

M_{21}=0,2, P=5 points – color; M_{22}=0,4, P=5 points – taste; M_{23}=0,2, P=5 points – odor; M_{24}=0,2, P=5 points – appearance;

M_{31}=0,25, P_{31}=3,3 m3/kg – specific volume; M_{32}=0,25, P_{32}=78% – porosity; M_{33}=0,25, P_{33}=11% – specific volume; M_{34}=0,25, P_{34}=0,48 kg / m3 – density;

M_{41}=0,5, P_{41}=25% – humidity; M_{42}=0,5, P_{42}=1,6 % – the index of moisture loss.

Substituting the selected values of weighting factors, basic indicators and indicators of the developed product, we have identified a comprehensive quality indicator biscuit semi-finished products «Sun» and «Gluten-free».

Qualitative assessment of biscuit semi-finished product quality makes it possible to comprehensively characterize it in terms of consumer requirements and determine the quantitative quality indicator, which for biscuit semi-finished products «Sun» by 16% exceeds the quality of the base product, and biscuit semi-finished product «Gluten-free» by 24%.

In addition, the study of the main characteristics and organoleptic quality indicators of biscuit semi-finished products «Sun» and «Gluten-free» was carried out on the basis of the development of a scale of sensory evaluation. Biscuit semi-finished product «Basic» was chosen as a control for comparison. The results are given in table. 3.13 and depicted in the form of profiles of appearance, color, sectional view, taste and smell (Fig. 3.14).

The appearance of biscuit semi-finished product using ECF involves a product of a given shape without cracks on a surface with a clean or finished surface. The color of the biscuit semi-finished products is rich, homogeneous and natural, for «Gluten-free» it is slightly yellower, typical of ECF. The finely porous elastic pulp, without traces of misalignment, retains its shape after aging. The taste and smell of biscuit semi-finished products with the use of ECF is balanced, clean, leaves a pleasant aftertaste, for «Gluten-free» taste and smell is typical of extruded corn products.

The presented technological process of biscuit semi-finished products production using ECF does not require significant changes in the organization of the confectionery shop and can be implemented both in specialized shops and in the restaurant.

Developed biscuit semi-finished products using ECF were presented at tastings, exhibitions, fairs, where they were highly praised by industry experts.

3.5 Development of recommendations for the use of biscuit semi-finished products with the use of ECF in the technology of flour confectionery and culinary products

The conducted experimental studies became the basis for developing recommendations for the use of biscuit semi-finished products with the use of ECF and semi-finished products «Gluten-free» in the culinary and flour confectionery technology. During technological testing, several types of confectionery products based on biscuit semi-finished product were developed, the recipe composition of which is given in table. 3. 14.

The technological process was carried out in accordance with the technological instructions to TU U 10.7-010566330-305: 2014.

Expanding the range of flour confectionery products based on biscuit semi-finished products «Sun» and «Gluten-free» can be done as follows:

- use of different types of fillings;
- use of various finishing semi-finished products;
- changes in the shape of products, etc.

Table 3.13 – Results of sensory evaluation of biscuit semi-finished products

Index	№ of descriptor	Coefficient of weight of the descriptor	Characteristic	Score in points		
				Control	Sun	Gluten-free
Appearance	1	0,2	Correspondence of the form	5,0	5,0	5,0
	2	0,2	No cracks on the surface	4,9	5,0	5,0
	3	0,2	Naturalness	5,0	5,0	5,0
	4	0,2	Originality	4,2	4,7	4,7
	5	0,2	Attractiveness	4,6	4,7	4,8
Total score				4,74	4,88	4,9
The weighting factor of the indicator				0,3	0,3	0,3
Final score on the indicator				1,42	1,46	1,47
Color	1	0,2	Inherent in this type of product	4,9	5,0	5,0
	2	0,2	Unburned	5,0	5,0	5,0
	3	0,2	Homogeneity of color	4,6	4,8	4,9
	4	0,2	Color saturation	4,7	4,8	4,9
	5	0,2	Natural color	4,8	4,9	4,9
Total score				4,8	4,9	4,94
The weighting factor of the indicator				0,3	0,3	0,3
Final score on the indicator				1,44	1,47	1,48
View in section	1	0,2	No traces of negligence	5,0	5,0	5,0
	2	0,2	Homogeneity of porosity	4,7	4,8	4,9
	3	0,2	Springiness	4,8	5,0	4,7
	4	0,2	Elasticity	4,8	5,0	4,9
	5	0,2	Preservation of shape	4,8	5,0	4,7
Total score				4,82	4,96	4,84
The weighting factor of the indicator				0,2	0,2	0,2
Final score on the indicator				0,96	0,99	0,96
Taste and smell	1	0,2	Inherent in this type of product	4,9	5,0	5,0
	2	0,2	Pleasant	4,8	4,9	5,0
	3	0,2	Clean	4,8	4,9	5,0
	4	0,2	Flavor	4,7	4,9	5,0
	5	0,2	Aftertaste	4,8	4,9	4,9
Total score				4,8	4,92	4,98
The weighting factor of the indicator				0,2	0,2	0,2
Final score on the indicator				0,96	0,98	0,99
Total				4,78	4,9	4,9

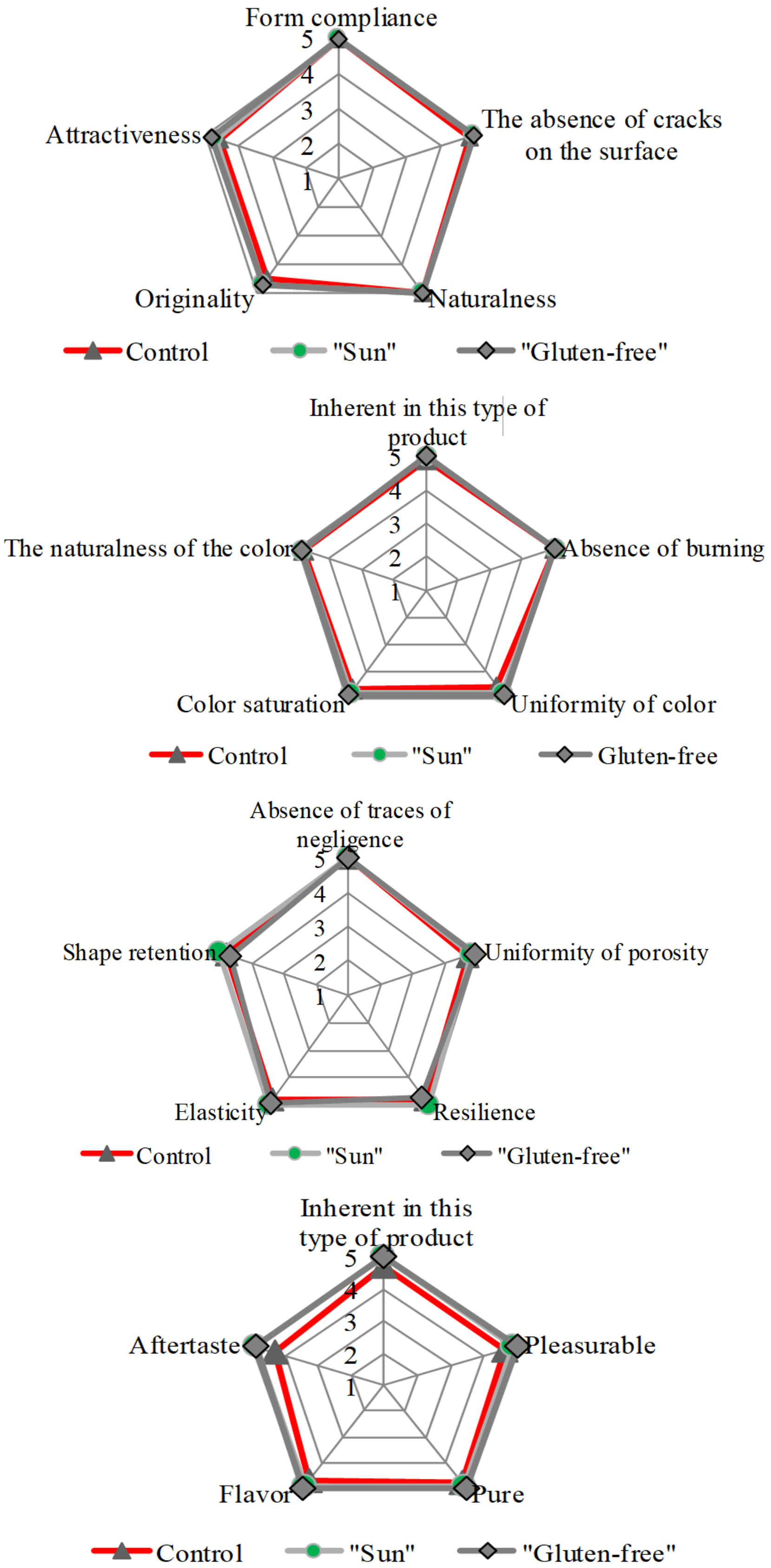


Figure 3.14 – Organoleptic profiles of biscuit semi-finished product: appearance (a), color (b), appearance of semi-finished products in section (c), taste and smell (d)

Table 3.14 – Prescription composition of confectionery products based on biscuit semi-finished products «Sun» and «Gluten-free»

Raw stuff	Consumption of raw materials per 1000 kg of product, kg			
	The fruit gluten free role	Cake «Biscuit» fruit	Cake «Biscuit» glazing	Cake «Biscuit» with cream
Wheat flour	-	260,0	260,0	260,0
ECF	305,80	80,70	80,70	80,70
Sugar	302,60	347,10	347,10 824,06	347,10
Eggs	634,40	578,50	578,50	578,50
Fruit filling	296,32	296,32	-	-
Powdered sugar	30,55	30,55	-	278,57
Butter	-	-	-	522,33
Condensed milk with sugar	-	-	-	208,92
Cognac	-	-	-	1,72
Chocolate butter	-	-	-	-
Cocoa powder	-	-	-	-
Vanilla powder	-	-	-	5,15
Raw egg white	-	-	-	-
Starchy molasses	-	-	82,40	-
Roasted walnut kernel	-	-	-	-
Total	-	-	-	-
Total prescription mixture	1265,92	1593,17	2172,76	1016,69
Output	1000,0	1000,0	1500,0	1000,0

On the basis of biscuit semi-finished products with the use of ECF it can be created a wide range of culinary products. Developed sweet dishes can be classified according to the functional purpose of the biscuit semi-finished product using ECF:

- biscuit semi-finished products with using ECF is the basis of a sweet (dessert) dish on which the filling is located;
- biscuit semi-finished products is a layer between one or different types of filler.

Sweet dishes are prepared directly in consumer packaging (ice cream cones), which allows to use a wide range of cream fillings with different structural and mechanical properties. Thus, it can be obtained layered sweet dishes, consisting of several layers of cream and biscuit semi-finished products. In addition, creams can be used as fillers, as well as as a surface finish. On the basis of analytical researches the assortment of sweet dishes in which biscuit semi-finished products with use of ECF can be used is defined (fig. 3.15).

Given the range of fillers, in particular, canapes, souffles, creams, it can be confirmed that the possibility of developing a wide range of culinary products. This allows to determine the directions of their development with the use of biscuit semi-finished products using ECF. Biscuit semi-finished products technology using ECF was developed. However, the proposed products based on them are not exhaustive, but only determine the technological direction of expanding the range of confectionery and culinary products.

A distinctive feature of the developed technology of biscuit semi-finished products «Gluten-free» is the production of fundamentally new products, which on key indicators - functional-technological, organoleptic, physico-chemical corresponds to the best national and world products analogues.

The safety of the technology is due to the refusal to use food additives, higher technological indicators, which increases the range of its use for the formation on its basis of a wide range of food products.

CONCLUSIONS

The analysis of native and foreign literature sources on the creation of flour confectionery technologies presented in the monograph showed the relevance of involving for these purpose products of processing grain raw materials by extrusion as a valuable source of substances necessary for the human body.

Analytical review of the literature and generalization of scientific and technical information on the research topic allowed to analyze current trends in biscuit semi-finished products technology and determine that a perspective direction is the study of technological indicators of extruded corn flour (ECF) and its use in biscuit semi-finished products technology for culinary and confectionery products.

In order to determine the nutritional value of ECF, its chemical composition, and nutritional and biological value were studied. It was found that the fiber content in ECF is 1%, 10 times more than in wheat flour. ECF contains proteins – prolamine and glutenin fractions, but they do not form gluten similar to wheat proteins. This allowed recommending the use of ECF in producing gluten-free biscuit semi-finished products.

The regularities of the process of dough formation of flour mixtures with the use of different concentrations of ECF and its influence on the rheological parameters of the dough and the quality of the biscuit semi-finished products are studied. The study of ECF concentrations from 5 mass % to 20 mass % in flour mixtures showed that the time of dough formation is reduced by half, and the water absorption capacity is increased by 3%. It was found that the flour mixture containing 20 mass % ECF can be recommended for biscuit semi-finished products, as the overall valorimetric evaluation of the dough deteriorates by only 7%, which eliminates the need for potato starch to reduce gluten.

The influence of ECF on the dynamics of changes in the state of moisture in biscuit cake dough has been studied. It was found that the addition of ECF to the biscuit dough system promotes moisture binding and in turn indicates a tendency to retain more moisture in the finished biscuit semi-finished products using ECF, which prolongs the shelf life of the finished biscuit semi-finished product.

A study of the moisture holding capacity and the effect of ECF concentrations in flour mixtures from 5 mass % to 100 mass % on the moisture content in the biscuit semi-finished products showed that the use of ECF causes a redistribution of moisture bonding forms. The amount of mechanically, adsorption and osmotically bound moisture decreases and the amount of bound moisture increases: up to 22.8%, 25.6%, 27.2% for samples with ECF content of 20 mass % and 100 mass % in accordance. This fact allowed to predict the role of ECF in extending the shelf life of biscuit semi-finished products.

By full-factor experiment, the regression and response surface equations were obtained, based on which the recipe composition was optimized and the technology of gluten-free biscuit semi-finished products based on 100% replacement of wheat flour on ECF with quantitative ratio of recipe components "eggs: sugar: 1: flour: 1.02. Thus, the percentage of the main prescription components was found: egg content 51%; white sugar content 24.4% and ECF content 24.6%.

The study of the microstructure of biscuit dough and semi-finished products using ECF allowed to substantiate the laws of stabilization of the foam system of biscuit dough using ECF. It was found that the complete replacement of wheat flour with ECF affects the stability of the biscuit dough foam in such a way that it increases by almost 40%.

Based on the study of organoleptic and microbiological indicators, the shelf life of new products for 30 days at a temperature of 20 °C and relative humidity not more than 75% is substantiated.

Using a systematic approach, based on the generalization of analytical and experimental research scientifically substantiated biscuit semi-finished products technology using ECF, which is normatively enshrined in TU U 10.7-010566330-305: 2014 Biscuit semi-finished product «Sun» and «Gluten-free» and TI to TU U 10.7 010566330-305: 2014, regulating the process of product production.

It is determined that the introduction of the technology reduces the selling price of biscuit semi-finished products «Sun» by 17.5% compared to control, and for biscuit semi-finished products «Gluten-free» there is a relative increase in selling price by 51.2% with an increasing overall quality indicator by 24%.

REFERENCES

1. Індекси промислової продукції за видами діяльності у 2019 році. URL: http://www.ukrstat.gov.ua/operativ/operativ2019/pr/iopp/iopp_u/iopp_19_u.htm (дата звернення 10.02.2020).
2. Rosell, C.M., Rojas, J.A. and Benedito, C. 2001a. Influence of hydrocolloids of Dough Rheology and Bread Quality. Food Hydrocol. 15:75. C. 81.
3. Дослідження можливості використання екструдату шроту амаранту в сиркових виробах. Нові технології та технічні рішення в харчовій та переробній промисловості: сьогодення і перспективи : матеріали IX міжнар. наук.-техн. Конф., м. Київ, 17–19 жовт. 2005 р. Київ, НУХТ, 2005. 160 с.
4. Справочник по гидроколлоидам : под ред. А. А. Кочетковой и Л. А. Сарафановой. СПб : ГИОРД, 2006. 536 с.
5. Иоргачева Е. Г., Макарова О. В., Котузаки Е. Н. Изменение показателей качества бисквитных полуфабрикатов на основе мучных композитных смесей. Збірник наукових праць ОНАХТ. 2014. Вип. 46. Т. 1. С. 112–117.
6. Василенко З. В. Мацикова О. В. Разработка технологии бисквита, обогащенного инулином. Кондитерское и хлебопекарное производство, 2005. № 11. С. 8.

7. Склад бісквіта з морквяним пюре: пат. 83984 Україна: МПК A21 D 13/00 (2013.01). № u 201303608/13; заявл. 22.03.2013; опубл. 10.10.2013, Бюл. № 10. 4 с.
8. Спосіб виробництва бісквітного напівфабрикату: пат. 35288 Україна: МПК (2006) A21D 13/00. № u 200804712; заявл. 11.04.2008; опубл. 10.09.2008, Бюл. №17, 4 с.
9. Композиція інгредієнтів для приготування масляного БН: пат. 36082 Україна: МПК A21 D 13/00 (2006). № u 200806679; заявл. 15.05.2008; опубл. 10.10.2008, Бюл. № 19. 5 с.
10. Джабоева А. С., Думанишева З. С., Кабалоева А. С., Созаева Д. Р. Технология бисквитных полуфабрикатов с использованием порошков из дикорастущих плодов. Кондитерское и хлебопекарное производство. 2007. № 8. С. 4–6.
11. Бісквіт: пат. 64457 Україна: МПК (2011.01) A23G 3/00. № u 201104161; заявл. 06.04.2011; опубл. 10.11.2011, Бюл. № 21, 3 с.
12. Rababah, Taha M. Mahasnek Majdi A., Ereifej Khalil I. Effect of chickpea broad bean or isolated soy protein additions on the physicochemical and sensory properties of biscuits Al-J Food Science, 2006. 71. № 66. С. 438–442.
13. Иоргачева Е. Г., Макарова О. В., Капетула С. Використання амарантового борошна в технології виготовлення бісквітних напівфабрикатів. Хлібопекарська і кондитерська промисловість України, 2008. № 12. С. 20–23.
14. Новицкая Е. А., Миронова Е. М. Изучение потребительского спроса на бисквитные коржи, приготовленные с использованием ржаной муки. «Неделя науки – 2004»: матер. 37-й студ. науч.-техн. конф.; Орел ГТУ. Орёл, 2004. С. 22–24.
15. Спосіб одержання масляного бісквітного напівфабрикату: пат. 42270 Україна: A МПК A21 D 13/08. № u 2000127260; заявл. 18.12.2000; опубл. 15.10.2001, Бюл. № 9, 4 с.
16. Матвеева Т. В., Корячкина С. Я. Мучные кондитерские изделия функционального назначения. Научные основы, технологии, рецептуры: монография. Орел: ФГОУ ВПО «Госуниверситет – УНПК», 2011. 358 с.
17. Спосіб приготування бісквітного напівфабрикату: пат. 27633 Україна: МПК A 21 D 13/08 № u 200706967; заявл. 21.06.2007; опубл. 12.11.2007, Бюл. № 18. 6 с.

18. Корячкина С. Я., Лазарева Т. Н., Кабанова Т. В., Годинов О. А., Холодова Е. Н. Использование нетрадиционного сырья в технологии бисквита. Хлебопродукты. 2015. № 6. С. 44–45.
19. Корячкина С. Я., Матвеева Т. В., Лазарев Т. Н. Применение сиропа олигофруктозы в технологии бисквитного полуфабриката. Хлебопродукты. 2012. № 2. С. 38–42.
20. Пищевые эмульгаторы и их применение / под ред. Дж. Хазенхюттля, Р. Гартела, В. Д. Широкова. СПб. : Професия: 2008. 288 с.
21. Спосіб виробництва низькокалорійного кондитерського виробу: пат. 108085 Україна: А МПК A23G 3/34 (2006.01). № u 201603107; заявл 25.03.2016; опубл. 24.06.2016, Бюл. № 12, 5 с.
22. Способ производства бисквитного теста: пат. РФ 2310330. № 2006113292/ 13 заявл. 19.04.2006, опубл. 20.11.2006, Бюл. № 32. 4 с.
23. Липатов И. Б. Разработка технологии и рецептур изделий из бисквитного и дрожжевого теста с использованием альгинатов и ламинарии: дис…к-та техн. наук: 05.18.15. С.-Пб, 2004. 121 с.
24. Новицкая Е. А., Миронова Е. М. Изучение потребительского спроса на бисквитные коржи, приготовленные с использованием ржаной муки. «Неделя науки – 2004»: матер. 37-й студ. науч.-техн. конф.; Орел ГТУ. Орёл, 2004. С. 22–24.
25. Лапушенко О. В. Завдання державного санітарно-епідеміологічного нагляду у забезпеченні державної політики в галузі харчування населення. Проблеми харчування. 2003. № 1. С. 5–7.
26. Спосіб виробництва масляного бісквіту «Полярна ніч»: пат. 34873 Україна: МПК (2006) A23 D 7/02 / № u 200803857; заявл. 27.03.2008; опубл. 26.08.2008, Бюл. № 16, 4 с.
27. Бісквітний напівфабрикат оздоровчо-профілактичного призначення: пат. 64455 Україна: МПК (2011.01) A23 G 3/00 / № u 201104159; заявл. 6.04.2011; опубл. 10.11.2011, Бюл. № 21, 5 с.
28. Спосіб приготування бісквітного напівфабрикату дієтичного призначення: пат. 35891 Україна: МПК (2006) A21D 13/00. № u 200805350; заявл. 24.04.2008; опубл. 10.10.2008, Бюл. № 19, 8 с.
29. Бісквітний напівфабрикат для хворих на цукровий діабет: пат. 83917 Україна: МПК (2013.01) A21D 13/00 /. № u 2013-1748; заявл. 13.02.2013; опубл. 10.10.2013, Бюл. № 19, 3 с.

30. Композиція для виготовлення бісквітного напівфабрикату: пат. 83989 Україна: МПК (2013.01) A21D 13/00. № u 201303613; заявл. 22.03.2013; опубл. 10.10.2013, Бюл. № 19, 3 с.
31. Бісквіт: пат. 64457 Україна: МПК (2011.01) A23G 3/00 / Кочерга В. І., Назар М. І.; заявник Національний університет харчових технологій UA – № u 201104161; заявл. 06.04.2011; опубл. 10.11.2011, Бюл. № 21, 11 с.
32. Спосіб виготовлення горіхово-макового бісквіто-подібного безхолестеринового напівфабрикату: пат. 25272 U МПК A21 D 13/08. № u 200606838; заявл. 19.06.2006; опубл. 10.08.2007, Бюл. № 12, 7 с.
33. Спосіб виробництва бісквітного напівфабрикату (варіанти): пат. 41637 Україна: А МПК A21 D 13/08. № u 2000127062; заявл. 8.12.2000; опубл. 17.09.2001, Бюл. № 8, 3 с.
34. Спосіб виробництва бісквіту: пат. 71788 Україна: МПК A21 D 13/08 (2006.01) / № u 201200659; заявл. 23.01.2012; опубл. 25.07.2012, Бюл. № 14, 2012 р.
35. Склад бісквіту спеціального призначення: пат. 30611 Україна: МПК (2006) A23 G 3/00. № u 200706087; заявл. 1.06.2007; опубл. 11.03.2008, Бюл. № 12, 8 с.
36. Тихомиров В. К. Пены. Теория и практика их получения и разрушения / 2-е изд. перераб. и доп. Москва : Химия, 1983. 264 с.
37. Murray B. S., Ettelaie R. Foam stability: Proteins and nanoparticles. Current Opinion in Colloid and Interface Science, 2004. Vol. 9, № 5. P. 314–320.
38. Горальчук А. Б. Наукове обґрунтування технологій напівфабрикатів збивних для кулінарної та кондитерської продукції з поліфазною дисперсною структурою: дис…к-та техн. наук: 05.18.16. Харьков, 2016. С. 326.
39. Ali J. Green, Karen A. Littlejohn, Paul Hooley, Philip W. Cox. Formation and stability of food foams and aerated emulsions: Hydrophobins as novel functional ingredients. Current Opinion in Colloid &Interface Science, 2013. Vol.18. P. 292–301.
40. Кисельова О. О. Виробництво випечених напівфабрикатів, печива пряників. URL: http://shag.com.ua/virobnictvo-vipechenih-napivfabrikativ-pechiva-pryanikiv-kisel.html (дата перегляду: 3.11.2015).

41. Спосіб виробництва бісквітного напівфабрикату: пат.71410 Україна: С2 МПК A21 D 13/08 (2006.01) № u 20031212789; заявл. 29.12.2003; опубл. 15.12.2006, Бюл. № 12, 6 с.
42. Зубченко А. В. Физико-химические основы технологи кондитерських изделий: учебник. 2-е изд. Воронеж : Воронеж. гос. технол. акад., 2001. 389 с.
43. Калачев М. И. Малые предприятия для производства сахарных и мучных кондитерских изделий. Москва : ДеЛи принт, 2009. 336 с.
44. Павлов А. В. Сборник рецептур мучных кондитерских и булочных изделий для предприятий общественного питания. Москва : Профи, 2016. 296 с.
45. Черевична Н. І. Розробка технології бісквітних напівфабрикатів з використанням мікробного полісахариду ксампану: дис…к-та техн. наук: 05.18.16. Харьков : 2010. 160 с.
46. Спосіб приготування бісквітного напівфабрикату: пат. 27633 Україна: МПК A21 D 13/08 (2006.01). № u 200706967; заявл. 21.06.2007; опубл. 12.11.2007, Бюл. № 12, 7 с.
47. Федоренко Г. М., Нечаюк И. И. К вопросу применения модифицированных крахмалов. Мясная индустрия. 2001. № 3. С. 12–13.
48. Руськина А. А., Попова Н. В., Науменок Н. В., Руськин Д. В. Анализ современных способов модификации крахмала как инструмента повышения его технологических свойств. Bulletin of the South Ural State University. Ser. Food and Biotechnology. 2017. Vol. 5, № 3. P. 12–20.
49. Головченко В., Лопатін Г., Ковбаса В. М. Екструдати, шрот і концентрати із зернобобових можна використовувати для створення нових видів харчових продуктів. Харчова і переробна пром-ть. 2001. № 1. С. 23–25.
50. Dickinson E. Colloids in food: ingredients, structure, and stability. Annual review of food science and technology. 2015. Т. 6. С. 211–233.
51. Остриков А. Н., Абрамов О. В., Рудометкин А. С. Экструзия в пищевой технологи. СПб : ГИОРД, 2004. 288 с.
52. Рудавська Г. Б., Аннєнкова Н. Б. Класифікація продуктів екструзійної технології та можливості розширення їх асортименту. Прогресивні техніка та технології харчових виробництв ресторанного господарства і торгівлі : Зб. наукових праць ХДУХТ. 2006. С. 264–271.

53. Оноприйчук О. О., Грек О. В. Аналіз біологічної цінності сиркових виробів із зерновими інгредієнтами. Таврійський науковий вісник. 2008. № 56. С. 139–146.
54. Притульская Н. В., Лобок И. И., Криклий Р. С., Харченко Ю. А., Казаченко С. В. Сухие завтраки, полученные методом экструзии. Оптимизация ассортимента и качества товаров народного потребления: Сб. научн. трудов КТЭИ. Киев : КТЭИ, 1992. С. 113–117.
55. Znou Z. et al. Enhanced thermal and antibacterial properties of cross-linked waxy maize starch granules by chitosan via dry heart treatment. International Journal of Food Science & Technology. 2015. Т. 50, № 4. Р. 899–905.
56. Бурцев А. В., Грицких В. А., Касьянов Г. И. Современная техника и технология термопластической экструзии в производстве «сухих завтраков». Краснодар : Экоинвест. 2004. 112 с.
57. Ковбаса В. М., Дорохович А. М, Хіврич Б. І. Застосування екструзії у виробництві нових харчових продуктів. Київ : Укр ІНТЕІ, 1995. 63 с.
58. Поліпшувач для хлібобулочних виробів з соєвими продуктами: пат. 5883 А Україна: МПК7 А21 D8/02. № заявл. 15.11.202; опубл. 15.08.2003, Бюл. № 8. 2 с.
59. Дробот В. І., Писарець О. П., Кравченко І. М. Використання кукурудзяної крупи у виробництві пшеничного хліба. Хранение и переработка зерна. 2013. № 9. 174 с.
60. Владимирова Е. Г., Ушакова Г. И., Кунарева О. П. Биохимия зерна, хлебопечения. Оренбург : ОГУ. 2004. С. 61.
61. Магомедов Г. О., Брехов А. Ф. Техника и технология получения пищевых продуктов термопластической экструзией. Воронеж : ВГТА, 2003. 168 с.
62. Остриков А. Н., Магомедов Г. О., Дерканосова Н. М. Технология экструзионных продуктов: учеб. пособ. СПб : Проспект Науки, 2007. 202 с.
63. Ковбаса В. М., Миронова М. Т., Ковальов О. В. та ін. Перетворення білкових речовин у процесі екструзійної обробки. Київ : УкрІНТЕІ, 1996. 19 с.
64. Ковбаса В. М. Наукове обґрунтування високотемпературної екструзії природних біополімерів та розроблення раціональних технологій харчоконцентратів і хлібопродуктів поліпшеної якості: дис…д-ра техн. наук: 05.18.01. Київ : 1998. 338 с.

65. Rao M. A. Rheology of food gum and starch dispersions. Rheology of fluid, semisolid, and solid foods. Springer US.2014. C. 161–229.
66. Хвыля С. И., Пчелкина В. А. Микроструктурные особенности растительных белковых продуктов для мясной промышленности. Все о мясе. 2011. № 2. С. 10–12.
67. Хелдт Ганс-Ваньльтер Биохимия растений / пер. с англ. М. А. Брейгиной, под. ред. А. М. Носова, В. В. Чуба. Москва : Бином. Лаборатория знаний. 2011. С. 471.
68. Кудряшова Е. В. Функционирование и структура белков в коллоидных системах, на поверхности раздела фаз и в микроэмульсиях: автореф. дис. ... д-ра хим. наук. Москва : 2009. 50 с.
69. Литвяк В. В. Современные технологии получения набухающих крахмалов. Пищевая промышленность: наука и технологии. 2009. № 2 (4). С. 64–68.
70. Kapelko-Zeberska M., Zieba T., Sngh A.V. Physically and chemically modified starches in food and non-food industries. Surface Modfication of Biopolymers. 2015. С. 173.
71. Климова Е. В. Возможности использования микроскопии для исследования состояния липидов, крахмалов, белков, камедей и др. веществ в пищевых продуктах с целью повышения их качества. Пищевая и перерабатывающая промышленность. 2008. № 3. С. 37–39.
72. Gidley M. G. Starch Structure. Function Relationships: Achievements and Challenges. Starch: advances in structure and function. Great Britain: Royal Society of Chemistry, 2001. P. 1–7.
73. Rosicka Kaczmarek J. et al. M. Composition and thermodynamic properties of starches from facultative wheat varieties. Food Hydrocolloids. 2016. T. 54. P. 66–76.
74. Ashogbon A. O., Akintayo E. T. Recent trend in the physical and chemical modification of starches from different botanical sours: A reviser. Starch-Starke. 2014. T 66. № 1–2. C. 41–57.
75. Milani J., Maleki G. Hydrocolloids in food industry. INTECH Open Access Publisher, 2012. ULR: hptt://cdn.intechopen.com/pdfs/29151.pdf.
76. Heiss R. Lebens mittel technlogie: Bitechnologische, chemische, mechanische und thermische Verfahren der Lebensmittel verarbetung. Springer, 2003. C. 523–539.

77. Be Miller J. N., Whistler R. L. (ed.). Starch: chemistry and technology. Academic Press, 2009. ULR: http://www.sciensdirect.com/science/article/pii/S0924224496100364.
78. Waterschoot J. et al. Production, structure, physicochemical and functional properties of maize, cassava, wheat, potato and rice starches. Starch-Starke. 2015. T. 67. № 1–2. P 14–29.
79. Yuryev V. etc. Starch: achievements in understanding of structure and functionality. Nova Publishers, 2006. C. 315.
80. Ферт К. Уайтауз. Выбор и использование гидроколлоидов. Пищевая промышленость. 2008. № 10. С. 76.
81. Huang Z. Q. et al. Ball-miling treatment effect on physicochemical propertys and features for cassava and maize starches Comptes Rendus Chme. 2008. T. 11, № 1. C. 73–79.
82. Кряжев Н. В., Романов В. В., Широков В. А. Последние достижения химии и технологии крахмала. Химия растительного сырья. 2010. № 1. С. 115.
83. Халиков Р. М. Полисахариды модифицированных крахмалов в качестве технологических структурообразователей. Инновационная наука. 2015. № 3. С. 51–59.
84. Жушман А. И. Модифицированные крахмалы : монография. Гос. науч. учреждение «Всероссийский науч.-исслед. ин-т крамалопродуктов», Российская акад. с.-х. наук. Москва : Пищепромиздат, 2007. 340 с.
85. Lopez O. V. et al. Acetylated and native corn starch blend films produced by blown extrusion. Jornal of Food Engineering. 2013. T. 21. № 1. P. 1–22.
86. Современные технологии контроля качества: глютен. URL: http://www.zip-i.ru/gluten_podrobno (дата звернення: 20.11.2016).
87. World Health Organization (WHO). European Health for All Database (HFA_DB). URL: www: ho.dk, 2002.
88. Захарова И. Н., Боровик Т. Э., Рославцева Е. А. и др. Целиакия у детей: решенные и нерешенные вопросы этиопатогенеза. Вопросы современной педиатрии. 2011. № 4. С. 30–34.
89. Codex-Alimentarius 1981:118 Codex standard for special dietary use for persons into leant to gluten. Amendment: 1983 and 2015. Revision: 2008. / Joint FAO / WHO Food Standards Programme. 2015. 3 p.

90. Отчет. URL: http://stylab.ru/file/test_gluten220510.pdf (дата звернення: 20.11.2016).
91. Шнейдер Д. В. Теоретические и практические аспекты создания безглютеновых продуктов питания на основе повышенной биодоступности сырья: автореф. дис. ... док. техн. наук: 05.18.01. Москва : 2012. 52 с.
92. Барсукова Н. В. Разработка технологии пряничных изделий на основе безглютенового мучного сырья: автореф. дис. ... канд. техн. наук: 05.18.15. С-П. 2005. 20 с.
93. Смесь для приготовления диетического безклейковинного хлеба. URL: http://patentdb.su/3-1771645-smes-dlya-prigotovleniya-dieticheskogo-besklejjkovinnogo-khleba.htmlrel.
94. Барсукова Н. В. Решетников Д. А., Красильников В. Н. Пищевая инженерия: технологии безглютеновых мучных изделий. Хранение и переработка зерна. Днепропетровск : ООО ИА «АПК-ЗЕРНО». 2011. № 4. С. 43–46.
95. Дорохович В. В. Наукове обґрунтування та розроблення технологій борошняних кондитерських виробів спеціального дієтичного призначення: автореф. дис. … д-ра. техн. наук: 05.18.16. Київ : 2010. 39 с.
96. Цыганова Т. Б., Шнейдер Д. В., Костылева Е. В. Формирование рецептур для производства безбелковых и безглютеновых продуктов. Хлебопродукты. 2011. № 12. С. 44–46.
97. Домбровская Я. П., Аралова С. И. Разработка рецептур безглютеновых мучных кулинарных изделий повышенной пищевой ценности. Вестник ВГУИТ. 2016. № 4. С. 141–147.
98. Морозова А. А., Сокол Н. В. Рисовая мучка – альтернативное сырье для производства безглютеновых мучных кондитерских изделий. URL: https://cyberleninka.ru/article/n/risovaya-muchka-alternativnoe-syrie-dlya-proizvodstva-bezglyutenovyh-muchnyh-konditerskih-izdeliy.
99. Щеколдина Т. В., Христенко А. Г., Черниховец Е. А. Использование квиноа в производстве мучных кондитерских изделий для людей страдающих целиакией. Технология и товароведение инновационных пищевых продуктов. 2015. № 5 (34). С. 54–57.

100. Рензяева Т. В., Бакирова М. Е. Печенье из рисовой муки для специализированного питания. Технологии пищевой и перерабатывающей промышленности. АПК-продукты здорового питания. 2017. № 1. С. 49–54.
101. Camino M., Mancebo Patricia Rodriguez, Manuel Gómez Assessing rice flour-starch-protein mixtures to produce gluten free sugar-snap cookies. LWT – Food Science and Technology. 2016, Vol. 67. P. 127–132.
102. Manuel Gómez Mario M. Martínez. Changing flour functionality through physical treatments for the production of gluten-free baking goods. Journal of Cereal Science. 2016. Vol. 67. P. 68–74.
103. Драгилев А. И., Сезанев Я. М. Производство мучных кондитерских изделий: учеб. пособ. Москва : ДеЛи, 2000. С. 448.
104. ДСТУ 3355-96. Продукція сільськогосподарська рослинна. Методи відбору проб у процесі карантинного огляду та експертизи. Чинний від 1997-07-01. Київ : Держспоживстандарт України, 1997. 16 с.
105. ДСТУ ISO 1356.3:2003 Зернові, бобові та продукти їх помелу. Відбір проб. Чинний від 2005-07-01. Київ : Держспоживстандарт України, 2005. 18 с.
106. ДСТУ ISO 5984:2004. Корми для тварин. Визначення вмісту сирої золи методом озолення. Чинний від 2006-01-01. Київ : Держспоживстандарт України, 2005. 4 с.
107. Дробот В. І. Лабораторний практикум з технології хлібопекарського та макаронного виробництв: навч. посіб. Київ : Руслана. 2006. 345 с.
108. СОУ 15. 71-37-745:2008 Визначення водорозчинних вітамінів методом флуорометрії.
109. Барковский В. Ф., Городенцева Т. Б., Топорова Н. Б. Основы физико-химических методов анализа: учеб. Москва : Высш. школа, 1993. 247 с.
110. Молоко и молочные продукты. Метод измерения массовой доли общего азота по К’эльдалю и определение массовой доли белка: ГОСТ 23327-98. – [Введ. 200-01-01]. – Минск : Межгос. Совет по стандартизации, метрологи и сертификации. 2009. 8 с.
111. Горальчук А. Б. та ін. Технологія десертів молочних із використанням карагінанів : монографія. Харківський державний університет харчування та торгівлі. Харків : ХДУХТ, 2013. 122 с.

112. ДСТУ ISO 21415-1:2009 Пшениця та пшеничне борошно. Вміст клейковини. Частина 1. Визначення сирої клейковини ручним методом (ISO 21415-1:2006, IDT). – [Чинний від 2009-14-12]. – Київ : Держстандарт України, 2009. 18 с.
113. Боган В. И. и др. Совершенствование методов контроля качества продовольственного сырья и пищевой продукции. Молодой ученый, 2013. № 57. С 101–105.
114. Юрчак В. Г., Арсеньева Л. Ю. Технологічні розрахунки у хлібопекарському виробництві: за ред. В. І. Дробот. Київ : Кондор. 2010. С. 440.
115. Вода в пищевых продуктах и для пищевых продуктов: Н. И. Погожих [и др.]; Харк. гос. унив-т пит. и торговли. Харків : ХДУХТ. 2013. С. 177.
116. Неронов Ю. И., Гарайбех З. Ядерный магнитный резонанс в томографии и в спектральных исследованиях. учеб. пособ. СПб.: Санкт-Петербургский государственный институт точной механики и оптика (Технический университет). 2003. 84 с.
117. Даниленко О. Ф., Дьяков О. Г., Торяник О. І. Автоматизована система виміру ЯМР-спектрометра. Прогресивні техніка та технологія харчових виробництв ресторанного господарства і торгівлі. Зб. наук. Праць. Вип. 2. Харків : 2005. С. 314–342.
118. ДСТУ 7045:2009 Вироби хлібобулочні. Методи визначення фізико-хімічних показників. – [Чинний від 2009-01-07]. – Київ : Держстандарт України, 2009. 18 с.
119. Лурье И. С. Технология кондитерского производства. Москва : Агропромиздат, 1992. 399 с.
120. Горальчу А. Б. та ін. Реологічні методи дослідження сировини та харчових продуктів та автоматизація розрахунків реологічних характеристик: метод. посіб. Харківський державний ун-т харчування та торгівлі. Харків : ХДУХТ, 2006. 63 с.
121. Нилова Л. П., Калинина И. В., Науменко Н. В. Метод дифференциально-термического анализа в оценке качества пищевых продуктов. Вестник ЮУрГУ. Серия «Пищевые и биотехнологии». 2013. Вып.1. № 1. С. 43–49.
122. Гурський П. В. Технологія паст закусочних на основі сиру кисломолочного нежирного: автореф. дис. … канд. техн. наук. Харків : 2008. 353 с.
123. Бергб Л. Г. Введение в термографию. Москва : АН СССР, 1961. 486 с.

124. Пилоян Г. О. Введение в теорию термического анализа. Москва : Наука, 1964. 284 с.
125. Clausse D. (2010), Differential thermal analysis, differential scanning calorimetry, and emulsions, J. Therm. Anal. Cal., 101 (3), p. 1071–1077.
126. Haines P. J. (2012), Thermal Methods of Analysis: Principles, Applications and Problems, Springer Science & Business Media.
127. Klančnik1 G., Medved J., Mrvar P. (2010), Differential thermal analysis (DTA) and differential scanning calorimetry (DSC) as a method of material investigation, RMZ – Materials and Geoenvironment, 57 (1), pp. 127–142.
128. Квалиметрия. Методические указания по практическим занятиям.URL: http://files.lib.sfu-kras.ru/ebibl/umkd/104/u_lab.pdf (дата звернення 7.09.2016).
129. ДСТУ ГОСТ 30726-2002 Продукти харчові. Методи виявлення та визначення кількості бактерій виду Escherichia coli. Введ. 01.01.2003. Київ : Український науково-дослідний інститут стандартизації, сертифікації та інформатики, 2003. 7 с.
130. ГОСТ 26669-85 Продукты пищевые и вкусовые. Подготовка проб для микробиологических анализов. Взамен ГОСТ 10444.0-75; Введ. 01.07.86. Москва : Изд-во стандартов, 1986. 9 с.
131. ГОСТ 26670-91 (ISO 7218-85) Продукты пищевые. Методы культивирования микроорганизмов. Взамен ГОСТ 26670-85; Введ. 01.01.93. Москва : Изд-во стандартов, 1991. 9 с.
132. Продукты пищевые. Методы определения количества мезофильных аэробных и факультативно-анаэробных микроорганизмов: ГОСТ 10444.15-94. Введ. 01.01.97. Москва : Изд-во стандартов, 2010. 7 с.
133. ГОСТ 1444.12-88 (ISO 7954-87) Продукты пищевые. Методы определения количества дрожжей и плесневых грибов. Взамен ГОСТ 1444.12-75; ГОСТ 10444.3-75; ГОСТ 26888-86; Введ. 01.01.90. Москва : Изд-во стандартов, 1988. 8 с.
134. ДСТУ ISO 6579:2006 Мікробіологія харчових продуктів і кормів для тварин. Методика виявлення бактерій рода Salmonell aspp (ISO 6579:2002, IDT).
135. Методика разработки рецептур на новые и фирменные блюда (изделия) на предприятиях общественного питания. Москва : ВНИИОП, 1991. 19 с.
136. ДСТУ 3946-2000. Продукція харчова. Основні положення Держспоживстандарт України. Київ : 2000. 6 с.

137. Касилова Л. А., Крайнюк Л. Н. Методические указания по теме «Изучение методики отработки рецептур на кулинарною продукцию». Харьков : ХГАТОП, 1997. 16 с.
138. Сафонова О. Н. и др. Системное исследования технологий переработки продуктов питания. Харьков : ХГАТОП, 2000. 199 с.
139. Методичні рекомендації з формування собівартості продукції (робіт, послуг) у промисловості: наказ Міністерства промислової політики України № 373 від 09.07.07 р. Київ : ДІКЕД, 2007. 321 с.
140. Ратушный А.С. Математико-статистическая обработка опытных данных в технологии продуктов общественного питания; Метод. указ. Рос. экон. академия им. Г.В. Плеханова. М. : 1993. 176 с.
141. Черновьянц М. С. Систематические и случайные погрешности химического анализа. Москва : ИКЦ «Академкнига». 2004. 157 с.
142. Грачев Ю. П. Математические методы планирования экспериментов. Москва : Элеватор, 2000. 512 с.
143. Ананьев В. А. Анализ экспериментальных данных: учеб. пособ.: в 2 ч. Кемерово : ГОУ ВПО «Кемеровский госуниверситет», 2008. Ч. 1. 92 с.
144. Лапинская В. О., Басалай И. А., Бельская Г. В. Математическая обработка результатов анализа всхожести семян растений-галофитов в засоленных средах. Белорусский национальный технический университет. 2015. С. 333–335.
145. Дьяков В. П. Math Cad в матиматике: справочник. Москва : Горячая линия Телеком. 2007. 958 с.
146. Сойфер В. А. Комп'ютерна обробка зображень. Частина 2. Методи та алгоритми. Соросівський освітній журнал, № 3, 1996.
147. Дрейнер Н., Смит Г. Прикладной регрессионный анализ. Москва : Вильям, 2007. 912 с.
148. Журавлев Ю. И. Об алгебраическом подходе к решению задач распознавания или классификации. Проблемы кибернетики. Москва : Наука, 2005. Вып. 33. С. 5–68.
149. Стадник І. Я., Добротвор І. Г., Деркач А. М., Василів В. П. Методика і результати дослідження утворення пор в бублику «Подільському». SWorld. Сборник научных трудов, том 3, № 2 (39). 2015. С. 9–15.

150. Koruz J., Witczak M., Ziobro R., Juszczak L. The influence of flour of rheological properties of gluten-free dough and physical characteristics of the bread. Eur Food Res Technol. 2015. Vol. 240. P. 1135–1143.
151. Асоціація «Укркондпром». URL: http://ukrkondprom.com.ua.
152. Лисовская Т. О., Черная Н. В. Исследование аминокислотного состава белков муки кукурузной экструдированой. Техника технология пищевых производств: сб. науч. труд. Могилевский государственный университет продовольствия. Республика Беларусь, Могилев : 2013. Ч. 1. С. 144.
153. Лісовська Т. О., Чорна Н. В. Підвищення харчової цінності бісквітних напівфабрикатів шляхом використання борошна кукурудзяного екструдованого. Актуальні проблеми розвитку харчових виробництв, ресторанного та готельного господарств і торгівлі: зб. наук. пр. Харк. держ. ун-т. харч. та торг. Харків : ХДУХТ, 2013. Ч. 1. С. 30.
154. Абазовік І. В., Лісовська Т. О., Чорна Н. В. Перспективи використання борошна кукурудзяного екструдованого в технології бісквітних напівфабрикатів. Актуальні проблеми розвитку харчових виробництв, ресторанного та готельного господарств і торгівлі: зб. наук. пр. Харк. держ. ун-т. харч. та торг. Харків : ХДУХТ, 2012. С. 3.
155. Шаповаленко О. І., Перегуда М. А., Павлюченко О. С. та ін. Дослідження впливу екструзійного оброблення на вуглеводний комплекс зернових сумішей з насінням льону. Хранение и переработка зерна. 2009. № 3. С. 46–47
156. Химический состав пищевых продуктов: Справочные таблицы содержания основных пищевых веществ и энергетической ценности блюд и кулинарных изделий / под ред. Скурихина И. М., Шатерникова В. А. Москва : Легкая и пищевая промышленность, 1984. 327 с.
157. Химический состав российских продуктов питания: справочник. Под ред. член-корр. МАИ, проф. И. М. Скурихина и акад. РАМН, проф. В. А. Тутельяна. Москва : ДеЛи принт, 2002. 236 с.
158. Химический состав пищевых продуктов: под ред. И. М. Скурихина. Москва : ВО «Агропромиздат». 1987. 360 с.
159. Петрушевский В. В., Гладких В. Г., Винокурова Е. В. и др. Биологически активные вещества пищевых продуктов: справочник. Киев : Урожай, 1992. 192 с.

160. Коваленко А. А. та ін. Технологія десертів з використанням стабілізаційних систем на основі крохмалю: монографія. Харк. держ. ун-т харч. та торгівлі. Харків :ХДУХТ, 2010. 136 с.
161. Пивоваров П. П., Захаренко В. О., Трощий Т. В. Удосконалення методології експертизи поруватих харчових продуктів: монографія. Харк. держ. ун-т харч. та торгівлі. Харків : ХДУХТ, 2012. 348 с.
162. Лісовська Т. О., Чорна Н. В., Дьяков О. Г. Дослідження реологічних властивостей бісквітного тіста з використанням екструдованого кукурудзяного борошна. Восточно-Европейский журнал передовых технологий. 2016. № 2/11 (80). С. 19–23.
163. Сборник рецептур мучных кондитерских и булочных изделий для предприятий общественного питания. Москва : Профи, 2016. 296 с.
164. Лісовська Т. О., Чорна Н. В., Шпилик О. Б. Дослідження впливу екструдованого кукурудзяного борошна на реологічні показники бісквітного тіста. Міжнародна науково-технічна конференція «Стан і перспективи харчової науки та промисловості», 8–9 жовтня 2015 р.: Тернопіль: ТНТУ, 2015. С. 29.
165. Лісовська Т. О., Чорна Н. В., Юкало В. Г. Вивчення структурно-механічних характеристик тіста на основі борошняних сумішей з екструдованим кукурудзяним борошном. Науковий вісник Львівського національного університету ветеринарної медицини та біотехнологій імені С. З. Ґжицького. 2016, т 18, № 2 (68). С. 51–55.
166. Sing J., Kaur L., McCarthy O. J. Factors influencing the physico-chemical, morphological, thermal and rheological, properties of some chemically modified starches for food applications – A review: Food hydrocolloids. 2007. Т. 21. № 1. P. 1–22.
167. Ahmed J. et al. Impact of hight pressure treatment on functional, rheological, pasting and structural properties of lentil starch dispersions. Carbohydrate Polymers. 2016. Т. 152. С. 639–647.
168. Муратова Е. И., Смолихина П. М. Реология кондитерськких масс: монография. Тамбов : Изд-во ФГБОУ ВПО «ТГТУ», 2013. 188 с.
169. W. P. Edwards. The Science of Bakery Products. Royal Society of Chemistry, 2007. 259 p.

170. Weibiao Zhou, Y. H. Hui. Bakery Products Science and Technology, 2nd Edition. Wiley-Blackwell, 2014. 776 p.
171. Дорохович В. В. Ганоцька С. О. Розробка технології бісквітних напівфабрикатів на фруктозі. Ресторанне господарство і туристична індустрія в ринкових умовах: зб. наук. пр. Київ : КНТЕУ, 2004. С. 37–43.
172. Матвеева Т. В., Корячкина С. Я., Корячкин В. П., Агаркова Е. В. Влияние овсяной и ячменной муки на качество бисквитного полуфабриката. Хранение и переработка сельхоз. сырья. 2008. № 6. С. 74–77.
173. Черевична Н. І., Самохвалова О. В., Олійник С. Г. Нова технологія бісквітних напівфабрикатів з біополімером ксампаном. Вісник Харк. нац. техн. ун-ту сільськ. госп. ім. П. Василенка : зб. наук. праць. Х., 2007. Вип. 58: Сучасні напрямки технології та механізації процесів переробних і харчових виробництв. С. 329–334.
174. Прочан А. В., Чудик Ю. В., Сафонова О. М., Гавриш Т. В., Захаренко В. А. Використання борошна із зернових сумішей у виробництві борошняних кондитерських виробів. Зернові продукти і комбікорми, 2001. № 1. С. 37–47.
175. Лісовська Т. О., Шуранкова В. С., Чорна Н. В. Амілографічні дослідження борошняних сумішей. Інноваційні технології розвитку у сфері харчових виробництв, готельно-ресторанного бізнесу, економіки та підприємництва: зб. наук. пр. Харк. держ. ун-т. харч. та торг. Харків : ХДУХТ, 2014. Ч. 1. С. 22.
176. Лісовська Т. О., Деркач А. В., Стадник І. Я. Вивчення можливості використання екструдованого кукурудзяного борошна в технології борошняних кондитерських виробів оздоровчого призначення. Наукові праці НУХТ. 2017, т. 23, № 5, частина 2. С. 108–115.
177. Лісовська Т. О., Деркач А. В., Стадник І. Я., Сухенко Ю., Василів В. Екструдоване кукурудзяне борошно для дієтичного харчування. Продовольча індустрія АПК. 2017. № 11–12. С. 40–43.
178. Clausse D. (2010). Differential therm alanalysis, differential scanning calorimetry, and emulsions, J. Therm. Anal. Cal., 101 (3), pp 1071–1077.
179. Haines P.J. (2012), Thermal Methods of Analysis: Principles, Applications and Problems,Springer Science & Business Media.

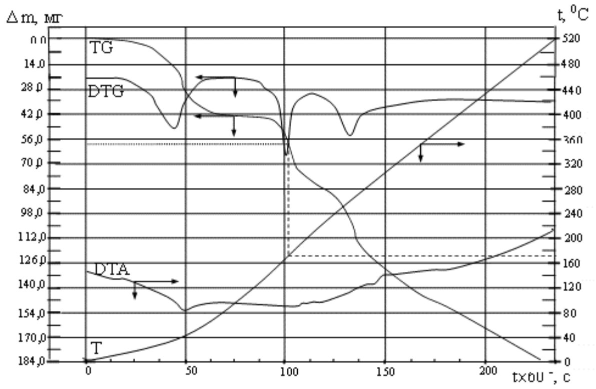
180. Tetiana Lisovska, Olga Rybak, Mykola Kuhtyn, Nina Chorna Investigation of water bindingin sponge cake with extruded corn meal. Ukrainian food journal. 2015. Vol. 4, Issue 3. C. 413–422.
181. Klančnik1 G., Medved J., Mrvar P. (2010), Differential thermalanalysis (DTA) and differentials canning calorimetry (DSC) as a method of material investigation, RMZ – Materials and Geoenvironment, 57 (1), pp. 127–142.
182. Eliasson A.C. Starch in food: structure, function and applications. – Cambridge: Wood head Publishing Limited, 2004. 605 p.
183. Лісовська Т. О., Чорна Н. В. Вивчення впливу екструдованого кукурудзяного борошна на стан вологи в бісквітному тісті. Проблеми енергоефективності та якості в процесах сушіння харчової сировини. Всеукраїнської науково-практичної конференції. Харків: ХДУХТ, 2017. С. 27–28.
184. Лісовська Т. О., Рибак О. М., Вічко О. І., Чорна Н. В. Термогравіметричний аналіз бісквітного напівфабрикату з кукурудзяним борошном у процесі зберігання. Продовольча індустрія АПК. 2016. № 1–2. С. 23–28.
185. Schiraldi A., PiazzaL., Riva M., Bred Staling: A Calorimetric Approach. Cereal Chemistry. 1996. № 73 (1). P. 32–39.
186. Chen P. L., Long Z., Ruan R., Labuza T. P. Nuclear Magnetic Resonance Studies of Water Mobility in Bread during storage. Lebensmittel-Wissenschaftund Technologie. 1997. № 30 (2). P. 178–183.
187. Лісовська Т. О., Деркач А. В., Кушнірук Н. В., Стадник І. Я. Вивчення екструдованого кукурудзяного борошна для створення борошняних кондитерських виробів оздоровчого призначення. Міжнародна науково-технічна конференція «Стан і перспективи харчової науки та промисловості», 11–12 жовтня 2017 р. : Тернопіль: ТНТУ, 2017. С. 96.
188. Юкало В. Г., Лісовська Т. О., Кушнірук Н. В., Джур Я. Б. Вивчення можливості використання екструдованого кукурудзяного борошна в технології безглютенового бісквітного напівфабрикату. Міжнародна науково-технічна конференція «Стан і перспективи харчової науки та промисловості», 8–9 жовтня 2015 р.: Тернопіль : ТНТУ, 2015. С. 71–72.
189. Лисовская Т. О., Юкало В. Г., Черная Н. В. Изучение возможности использования экструдированой кукурузной муки в технологии бисквита для диетического питания // MAISTO CHEMIJA IR TECHNOLOGIJA. 2016. T. 50, Nr. 1. C. 36–44.

190. Склад бісквітного напівфабрикату безглютенового. пат. на корисну модель № 108458, Україна МПК А 23 D3/36. № а 2014 11597; заявл. 27.10.2014; опубл. 25.07.2016, Бюл. №14. С. 4.
191. Чорна М. В., Глухова С. В. Формування ефективності інноваційної діяльності підприємства: монографія. Харків : ХДУХТ, 2012. 210 с.
192. Бісквітний напівфабрикат «Сонечко»: пат. № 87876 Україна: МПК А 23 G 3/00. № u 201309850; заявл. 08.08.2013, опубл. 25.02.2014; Бюл. № 4. 5 с.
193. Офіційний сайт ТОВ «Магнум СП». URL: http://magnum-nm.uaprom.net/.
194. Чухрай Н. І., Стегницький А. В. Комплексне оцінювання науково-технічних розробок на ранніх етапах інноваційного процесу. Маркетинг і менеджмент інновацій. 2015. № 1. С. 11–22.
195. Лісовська Т. О., Хмаладзе Т. К., Чорна Н. В. Кваліметричне оцінювання якості бісквітних напівфабрикатів. Інноваційні технології розвитку у сфері харчових виробництв, готельно-ресторанного бізнесу, економіки та підприємництва: наукові пошуки молоді: Всеукр. науково-практ. конф. молодих учених і студентів. ХДУХТ. Харків : ХДУХТ, 2017. Ч. 1. С. 30–31.

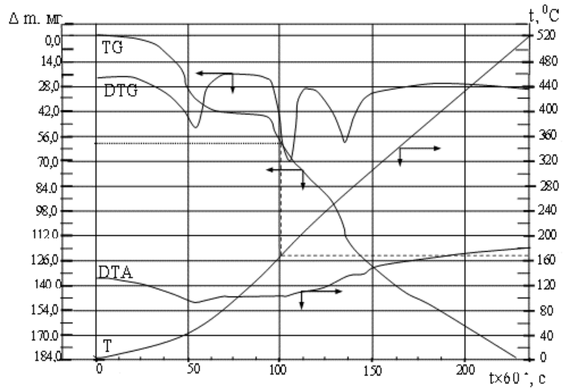
APPENDIX

Derivatogram of biscuit semi-finished products with ECF

Thermogravimetric studies were performed in ceramic crucibles under a quartz cap weighing 2 g, on a derivatograph DERIVATOGRAPH Q-1500D, in dynamic mode. Al2O3 calcined to 1500 °C was used as a standard. The samples were heated to 500 °C with a heating rate of 2.5 °C/min Determination of the forms of moisture connection with the components of the biscuit semi-finished products was carried out on the basis of analysis of temperature curves (T curve), changes in mass (TG curve) and its derivative (DTG curve), and enthalpy (DTA curve).

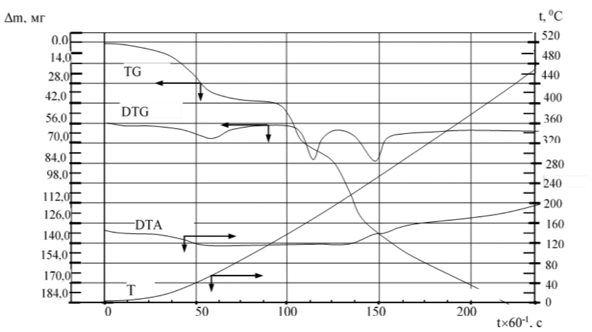


a) control

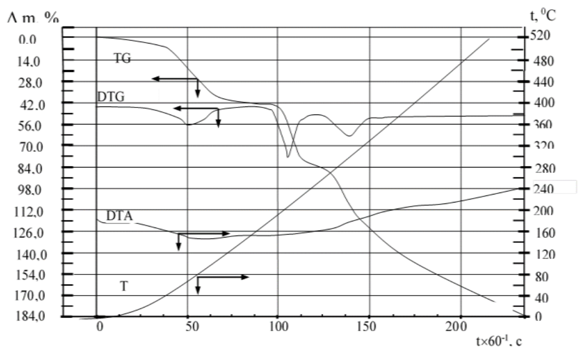


b) «Sun»

Figure A.1 – Derivatograms of biscuit semi-finished products
after 24 · 60 2s of storage:
a) control; b) «Sun»

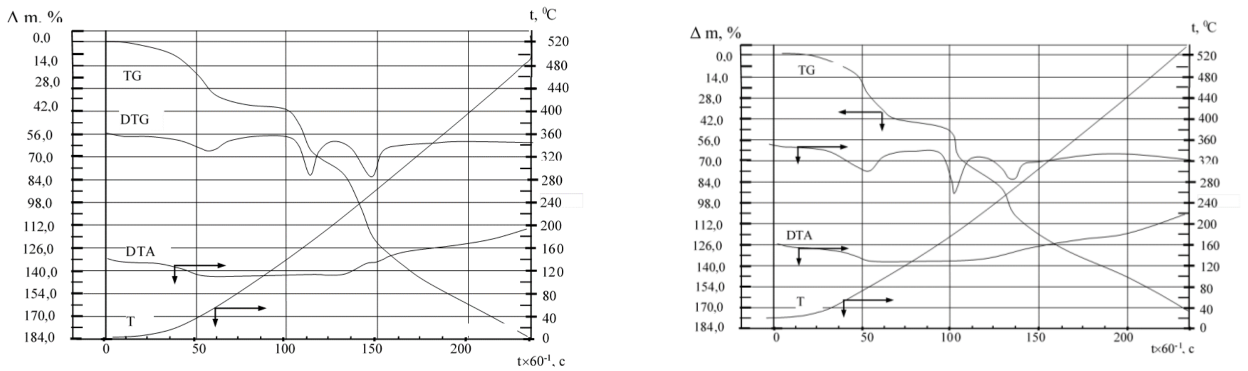


a) control



b) «Sun»

Figure A.2 – Derivatograms of biscuit semi-finished products
after 48 · 60 2s of storage:
a) control; b) «Sun»



a) control b) «Sun»

Figure A.3 – Derivatograms of biscuit semi-finished products after 72 · 60 2s of storage:
a) control; b) «Sun»

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ТЕХНОЛОГІЯ БІСКВІТНОГО НАПІВФАБРИКАТУ З ВИКОРИСТАННЯМ ЕКСТРУДОВАНОГО КУКУРУДЗЯНОГО БОРОШНА

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