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THE INFLUENCE OF GLUTEN-FREE FLOURS ON THE QUALITY INDICATORS OF BISCUIT SEMI-FINISHED PRODUCTS

Abstract

The article is devoted to the research of applicability of gluten-free flours from cereal crops and from by-products of cereal crop processing - ground crumbs sifted out in a process of flake production from rice, corn and millet during the production of biscuit semi-finished products. Taking into account that viscosity is an important technological characteristic of foam-like biscuit dough, as it determines foam strength and dispersed medium stability, the influence of gluten-free flours on the structural and rheological properties of biscuit dough was studied. It is determined that the substitution of wheat flour for cereal flours leads to viscosity reduction of the dough as a consequence of absence of gluten-forming proteins in them. A comparative analysis of changes in viscous properties of biscuit dough based on flour from flakes crumb while warming it up to 60°C with dough based on cereal flours and dough based on wheat flour was held. It is shown that the presence of partially gelatinized starch granules in flour from flake crumb, as a result of technological peculiarities of their extraction, promotes greater demonstration of thickening properties already at the initial stage of baking than in cereal flours. This leads to an increase of dough viscosity and formation of desired rheological characteristics, which provide the porous structure of finished products. To provide the high quality of gluten-free biscuit semi-finished products, the recipe composition of gluten-free biscuit semi-finished product, based on flour mixture from millet flakes crumb, corn and rice flour, was optimized by using the method of mathematical design of experiments.

The porosity indicator was chosen as the criteria for the evaluation of influence of proportion of gluten-free flours on the quality of biscuit semi-finished products. The response surfaces of dependency of biscuit porosity from mass ratio of recipe components in the composite mixture were obtained. It was confirmed experimentally that the use of pre-gelatinized acetylated modified starches during the production of gluten-free biscuit semi-finished products, facilitates the stabilization of the structural and rheological properties of foam structure - viscosity growth of biscuit dough because of foam-stabilizing property, which is particular to them. It was demonstrated that the obtained gluten-free biscuit semi-finished products based on flour composite mixtures with addition of modified starches, had high quality indicators. Based on the results of the research conducted, the recipe was formulated, technological parameters of production of new types of gluten-free biscuit semi-finished products were determined.

Key words: *biscuit semi-finished product, flour from by-products of processing cereal crops, viscosity, composite mixtures, optimization.*

Introduction

Despite the difficult economic conditions, pastries represent one of the most stable segments in the Ukrainian assortment structure of confectionery products [1, 2]. At the present time, one of the priority tasks of confectionery industry is the development of special pastry technology for therapeutic, prophylactic, dietary meals in congenital diseases. Scientific concept of creation of a new generation of products with targeted properties suggests that their ingredient composition and technology are being formed according to functional physiological and technological factors that determine the search for solutions for competitive meals creation. The prevalence of different types of allergic and other diseases and increase in demand for the products of functional orientation and special purpose force creators and manufacturers to reconsider their assortment policy and determine the relevance of development of new types of pastries based on gluten-free flours.

Literature review and problem definition

In recent years, a lot of investigations are devoted to the problem of food intolerance celiac disease and in particular [3-7]. The basic treatment for celiac disease is strict adherence to a gluten-free diet, which requires total exclusion of traditional bakery products from the food ration. For this reason, the development of new types of pastries based on gluten-free flours (buckwheat, rice, millet, corn) is particularly important. It will impart a functional orientation and create products for special purposes.

Semi-finished product for bakery confectionery products is a structured dispersed system. So the main difficulty of creating gluten-free products is to keep the necessary rheological properties of food products and provide the texture that most closely matches traditional products [8]. First of all, it is connected to the fact that wheat flour, the technological properties of which considerably determine the dough properties and the structure and quality of the products, is excluded from recipe. In the technological sense, solution of this problem comes from searching for optimal proportion of structure-forming components, justification of selecting the conditions of formation of a stable structure of food system, its structural and rheological properties which are characterized by viscosity, strength, plasticity and elasticity.

The study of the effect of corn, buckwheat and rice flour on the rheological, structural, and mechanical characteristics of the butter biscuit dough showed that the dough masses, based on gluten-free flour, differ from the dough masses, based on wheat flour, by higher module of elasticity, lower quantity of free water, and higher adhesive strength. To bring the technological characteristics of dough masses, based on gluten-free flour, closer to the technological characteristics of dough masses, based on wheat flour, the correction of recipe compositions was made. As a result, new types and rational technologies of gluten-free cookies based on rice, corn and buckwheat flour with the use of fructose, glucose and sucrose [9]

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were developed. The recipes and technologies of gluten-free gingerbread production were developed, based on rice and corn flour with the use of hydrocolloids, which provide requested properties of the dough and the finished product – potato starch, soy protein isolate, and natural polysaccharide xanthane gum [10]. The proportion of structure-forming components - guar and xanthane gum in the protein-free and gluten-free bakery premixes was optimized. It will allow to bake bread at home and get the product with the same organoleptic and physical-chemical properties as the bread made from wheat flour, as well as wafers and basis for cakes and other home-baked products [11]. As a result of the research conducted by the authors [12-14], the recipes of gluten-free sugar cookies and shortcrust semi-finished product based on rice and buckwheat flour and their mixtures in various proportions were developed.

In recent times, biscuits are very popular among the baked semi-finished products, they have high taste qualities, can serve as the basis for various cakes, pastries, rolls, and can be realized as finished products. The process of foam formation is very important to get a qualitative biscuit: it consists of dispersion of the egg and sugar mixture with the air, it is followed by the volume increase and the development of the internal surface of the system. The technology of biscuit production calls for the use of wheat flour in the weight percentage of 30% with weak or medium strength gluten and short-time dough kneading [15, 16]. This suggests the possibility of a complete replacement of wheat flour with non-breadbaking flours in this type of products without their quality degradation.

Research results and discussion

The aim of this work is the optimization of the recipes of biscuit semi-finished products on the basis of the study of the effect of gluten-free flours on the structural and rheological properties of the dough and quality indicators of biscuits to develop new products for special purposes. During the research, non-breadbaking flours were used: rice flour (RF), corn flour (CF), millet flour (MF), as well as the flour from by-products of processing - ground these crops crumbs sifted out in a process of flake production from rice (RFF) and millet (MFF). The dough for biscuits was prepared in 2 phases through cold mixing, and the basic biscuit was chosen as main control sample.

During the research, the viscosity was detemined. It is an important rheological characteristic of the biscuit dough as a foam. Thus, too low viscosity causes the rising of large gas bubbles of the dispersed phase to the surface, and the gas escapes into the atmosphere. Besides, if the viscosity is low, the flour may settle down and pile up on the bottom of a baking pan, and the dense lower layer is formed during the baking process. The high viscosity inhibits the development of the internal surface of the biscuit dough system and its lifting during the baking [17]. Accordingly, the viscosity of the biscuit dough is one of the factors defining the dispersed mediums, the ultimate structure of the baked semi-finished product. While the biscuit dough is being formed and baked, it is in the state of movement and heating .Its viscosity as the structured system changes irreversibly. For this reason, the viscous properties were studied under different temperatures.

The research results of the rheological properties of biscuit dough based on gluten-free flours under the temperature of 20 °C, particular to the production of biscuit semi-finished products according to traditional cold technology give evidence that the use of the flour from by-products of millet and rice processing and the corn flour, leads to the lowering of viscosity (Fig. 1).

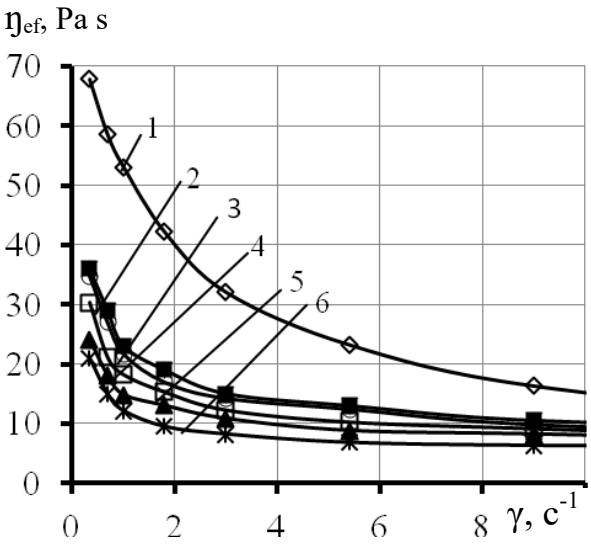

Fig.1 - Viscous properties of the dough for basic biscuit t=20 °C, based on: 1-wheat flour, 2 – RFF, 3 – RF, 4 – CF, 5 – MFF,6 – MF.

Thus, at the shear velocity of 1,8 c^{-1}, the viscosity of control sample was 42,2 Pa s, the viscosity of the sample based on RF – 17,0 Pa s, the viscosity of the sample based on RFF – 19,0 Pa s, the viscosity of the sample based on CF – 15,3 Pa s, on MF – 9,47 Pa s and on MFF – 13,0 Pa s. Obviously, it is connected to the absence of gluten-forming proteins in these types of flour and it leads to the dough structure relaxation and to some extent, to the dough dilution. While the shear of velocity increases, the biscuit dough viscosity decreases for all samples, which gives evidence about partial destruction of the structure.

Perhaps, it is caused by the fact that while the velocity of shearing stress increases, sphere-shaped air bubbles turn into ellipsoid ones, which facilitates the movement of the mass layers, and thereby causes the viscosity reduction, to some extent [17]. The variation of dough viscosity depending on the velocity of shear, tells that the most intensive viscosity reduction for all samples is at the velocity of shear up to 1,0 c^{-1}. Probably, it happens because of the air bubbles orientation towards the acting force of their destruction. The segments of the flow curve with smooth transformation to an almost constant viscosity correspond to the gradually increasing amount of the destroyed air bubbles. All samples show the tendency to constant viscosity at $\gamma = 5,4\ c^{-1}$. It should be pointed out that when the flour from flake crumbs was added to the dough, its viscosity was higher than in the dough based on gluten-free flours from cereal crops. It may be explained by the physical state of the flake`s

starch granules, determined by the parameters of moisture and heat treatment and by flattening them during their processing, and it leads to greater demonstration of their thickening qualities. It is possible that the changed state of the polysaccharides from the flake crumb flour, first of all, will contribute to the formation of necessary viscous and plastic properties of biscuit dough in the heating process during the baking. This is particularly important for the use of gluten-free flours – rice, corn and millet flour.

As a consequence, the variation of viscous properties of the dough during its heating was studied. The research results (Fig. 2) showed that as the temperature of the gluten-free biscuit dough based on RFF rose to 60 °C, its viscosity increased by 2,2 times, the based on MFF by 2,8 times, while for the dough based on RF and MF the viscosity increased by 1,9 and 2,4 times correspondingly.

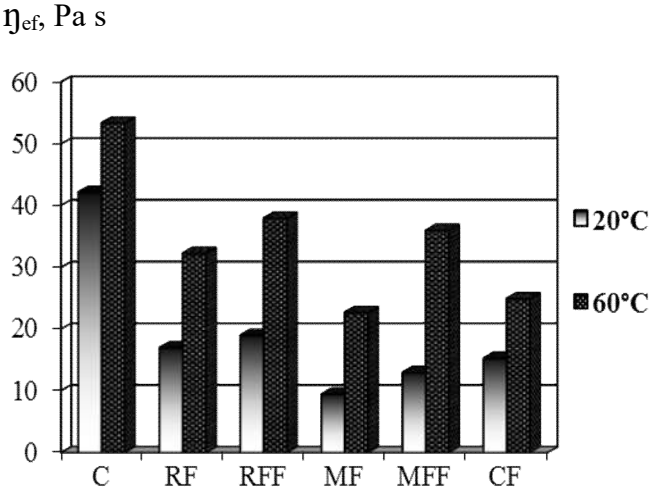

Fig.2 - Viscous properties of basic biscuit at its heating (γ = 1,8 c^{-1})

Such regularity is determined by the presence of partially gelatinized starch granules in the flour from flake crumbs as a result of technological particularities of their production. This promotes an earlier, than in gluten-free flours from cereal crops, manifestation of thickening properties at primary stage of baking and forming the desired rheological properties providing porous structure of finished products. Taking into account that the introduction of flour from flake crumbs leads to a greater increase in viscosity during the biscuit dough heating compared to the gluten-free flours from cereal crops, the flour from millet flake crumbs was chosen during the compounding composite mixtures. This will contribute to strengthening of the continuous phase structure, its thickening as a result of higher water binding, and more rapid formation of the required viscosity and plastic properties of semi-finished products during the baking. The inclusion of corn flour into a composite mixture is due to high organoleptic, physical and chemical quality indicators of the biscuit, based on this flour [18]. The addition of the rice flour into the composite mixture, though the gluten-free biscuit semi-finished products based on this flour had a small specific volume, based on the fact that the dough from on this flour possessed higher viscosity than the dough based on the other gluten-free flours. This is, possibly, because of the presence of large amounts of amylopectin (82%) in rice starch. It causes enhanced swelling ability, hygroscopicity and high viscosity of its water and flour suspensions [19]. In addition, rice flour gives the products a soft, creamy texture and sweet "creamy" flavor.

To provide the high quality of gluten-free biscuit semi-finished products, the optimization of the recipe compositions of composite flour mixtures was carried out. When determining their optimal ratio, the plan of three-factor Box's experiment for B3 type cube was implemented. The indicator of porosity (y), has been selected as criterion for evaluating the effect of ratio of gluten-free flours on the quality of the basic biscuit. It is an important characteristic that determines the texture of the finished product.

Processing of the research results by the method of least squares [20] with the use of sequential regression analysis and PLAN program [01] yielded the following regression equation:

$$y = 77{,}16 - 3{,}12x3 + 1{,}89x12 + 3{,}71\ x22 + 1{,}791x32, \quad (1)$$

where x_1, x_2, x_3 are coded values of factors - weight percentage of MFF, CF and RF correspondingly.

The reduced equation adequately describes the experimental data as the calculated value of Fisher criterion F = 3,23 is less than the critical value Fcr = 19.39 at the 5 % level of significance.

Calculated values of porosity y_{calc}, defined by equation (1), are in good agreement with the average experimental values of porosity y_{av} (relative errors are in the range of 0,19...3,20).

Using the obtained equation (1) the mass fractions of the components of the composite mixture, which provide maximum porosity of the biscuit semi-finished product were determined: MFF = 60% CF= 30% and RF= 10%. The geometrical interpretation of the equation (1), which gives a visual representation of the dependence of porosity of the semi-finished biscuit mass on ratio of MFF, CF and RF components is shown in Fig. 3.

High porosity of biscuit semi-finished products under a given correlation of the mixture components, is probably caused by the high content of flour from millet flake crumbs in it. The introduction of this type of flour helps to get a biscuit dough with higher viscosity, which may be caused by the degree of starch degradation in flakes. The damage of starch granules and their gelatinization are accompanied by their manifestation of thickening and gelling properties, the formation of a colloidal system, contributing to the texture formation, needed for producing the high-quality biscuits despite the exclusion of the wheat flour from recipe.

The rheological characteristics of the biscuit dough are in close dependence on its internal structure, its change during the technological process of biscuit production leads to the change of rheological parameters too. The conducted research has shown that full replacement of wheat flour with non-breadbaking flours, even in the case of flour from crumbs flakes, reduces the viscosity of the biscuit dough. Therefore, to control the quality of gluten-free biscuits semi –finished products, we investigated the feasibility of using modified starches

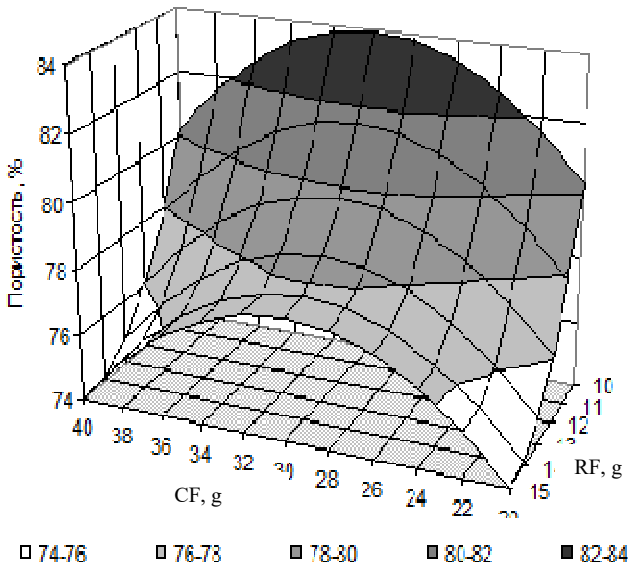

Fig. 3 - Response surface of dependence of biscuit semi-finished product on mass percentage of MFF, CF and RF.

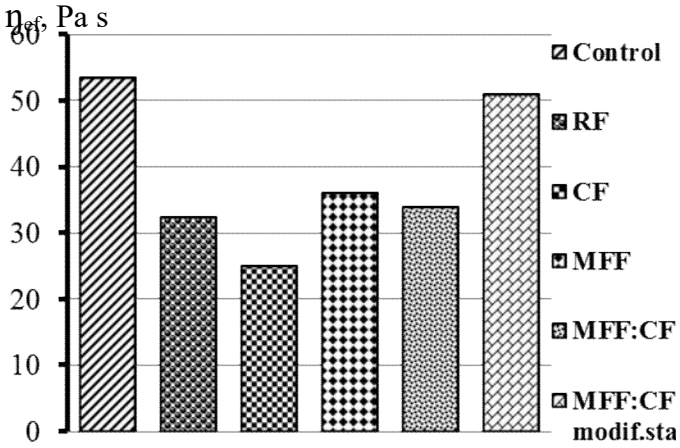

Fig. 4 - Effective viscosity of biscuit dough γ= 1,8 c^{-1}, t = 60 ºC.

as hydrocolloids during their production. They stabilize the dough structure and, as a result, the quality of finished products. During the research, the recipe quantity of potato starch was replaced by the modified starch Paselli BC .It is a pre-gelatinized distarch phosphate.

The results of the research of influence of modified starch on rheological properties of biscuit dough based on flour composite while heating up to 60 °C prove that the introduction of modified starch into the dough increases its viscosity (Fig. 4.). Thus, the effective viscosity of the biscuit dough based on composite mixture is 19.4% below the value of the control sample, while the dough with addition of the modified starch – 2,4 %. The higher viscosity of the dough when adding modified starch in comparison with potato starch is due to the fact that this type of starch is the acetylated ,"crosslinked" starch and it has an ability to form a stable starch paste and durable film. They are characterized by high resistance to mechanical stress and heat treatment [21]. So, the use of the modified starches in the production of biscuit semi-finished products can give the possibility to correct the rheological properties of the dough based on gluten-free flours, predetermining the quality indicators.

The use of composite mixtures MFF, CF and RF with the modified starch addition during production of biscuit semi-finished products allows to lower baking losses by 2,5 %, which refers to the opportunity to increase the output of finished products, it allows to increase the specific volume by 9 cm^3/g, enhance the porosity by 6,3 % and increase the relative plasticity crumb by 3,0 %.

Conclusions

Thus, while studying the effect of gluten-free flours on structural and rheological properties of biscuit dough, it was found that the replacement of the wheat flour is accompanied with a decrease in its viscosity. It was demonstrated that the use of the flour from flake crumbs during biscuit production is followed by huge increasing of dough viscosity already at the beginning of the baking, due to the better display of their thickening properties as compared to the samples on the gluten-free flours from cereal crops. The use of modified starches in the technology of gluten-free biscuit semi-finished products contributes to the stabilization of structural and rheological properties of foamy structure of the dough, which provides the formation of the developed structure of finished products. Based on the conducted research, the recipe was developed and optimized, technological parameters of new gluten-free biscuit semi-finished products “Ulybka” were determined. It was confirmed that the obtained gluten-free biscuit semi-finished products based on flour composite mixes with the introduction of modified starches had high quality and consumer characteristics. This will allow to expand the range of products for special purposes, and to diversify the diet of people with celiac disease.

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ВЛИЯНИЕ БЕЗГЛЮТЕНОВЫХ ВИДОВ МУКИ НА ПОКАЗАТЕЛИ КАЧЕСТВА БИСКВИТНЫХ ПОЛУФАБРИКАТОВ

Аннотация

Данная статья посвящена изучению целесообразности использования безглютеновых видов муки из крупяных культур, в том числе из побочных продуктов их переработки – измельченной крошки, отсеянной при приготовлении хлопьев: рисовых, кукурузных, просяных, при производстве бисквитных полуфабрикатов. Учитывая, что вязкость является важным технологическим свойством пенообразного бисквитного теста, поскольку обуславливает прочность пены и определяет стабильность данных диспергированных сред, было изучено влияние безглютеновых видов муки на структурно-реологические свойства бисквитного теста. Установлено, что замена пшеничной на данные виды муки приводит к снижению вязкости теста вследствие отсутствия в них клейковинных белков. Проведен сравнительный анализ изменения вязкостных свойств бисквитного теста на основе муки из крошки хлопьев при прогревании его до 60 °С с одноименными видами муки и пшеничной. Показано, что наличие в муке из крошки хлопьев частично клейстеризованных крахмальных гранул, в результате технологических особенностей их получения, способствует большему проявлению загущающих свойств уже на начальной стадии выпечки, чем у одноименных видов муки. Это приводит к увеличению вязкости теста и формированию желаемых реологических характеристик, обеспечивающих пористую структуру готовых изделий.

Для обеспечения высокого качества безглютеновых бисквитных полуфабрикатов методом математического планирования экспериментов оптимизирован рецептурный состав безглютенового бисквитного полуфабриката на основе смеси муки из крошки просяных хлопьев, кукурузной и рисовой муки. Критерием оценки влияния соотношения безглютеновых видов муки на качество бисквитных полуфабрикатов был выбран пока-

затель пористости. Получены поверхности отклика зависимости пористости бисквита от массового соотношения рецептурных компонентов композитной смеси.

Экспериментально подтверждено, что применение предварительно клейстеризованных, ацетиллированных модифицированных крахмалов при производстве безглютеновых бисквитных полуфабрикатов способствует стабилизации структурно-реологических свойств пенной структуры – увеличению вязкости бисквитного теста вследствие присущим им пеностабилизирующим свойствам. Показано, что полученные безглютеновые бисквитные полуфабрикаты на основе мучных композитных смесей с внесением модифицированных крахмалов имели высокие показатели качества. На основании проведенных исследований разработана рецептура, определены технологические параметры производства новых видов безглютеновых бисквитных полуфабрикатов.

***Ключевые слова**: бисквитный полуфабрикат, мука из продуктов переработки риса, кукурузы и проса, вязкость, композитные смеси, оптимизация.*

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