CHAPTER 11

INNOVATIVE TECHNOLOGIES OF HEALTH-PROMOTING FLOUR CONFECTIONERY PRODUCTS

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INTRODUCTION

According to the World Health Organization, maintaining a healthy lifestyle, in which nutrition plays a decisive role, is one of today's most pressing issues. Psychological stress, low physical activity, unsatisfactory quality of food products, as well as global crisis phenomena, including pandemics and military conflicts, lead to weakened immunity and an increase in nutrition-related diseases, particularly alimentary-dependent disorders such as obesity, diabetes, cardiovascular diseases, and metabolic disorders.

Modern living conditions have resulted in an increasing number of people suffering from gluten intolerance and celiac disease, a chronic genetically determined disorder characterized by persistent intolerance to cereal proteins with the development of small intestinal mucosal atrophy and associated malabsorption syndrome. According to the Ukrainian Celiac Disease Association, approximately 2.000 people in Ukraine suffer from this disease, and their number increases annually, corresponding to the global tendency of diagnosing celiac disease in approximately 1 out of 133 individuals[1]. Gluten may negatively affect not only individuals with allergies but also healthy people, causing digestive disorders such as diarrhea, heartburn, and flatulence.

As world experience demonstrates, solving the problem of correcting dietary patterns is almost impossible solely through increasing production and expanding the assortment of traditional food products. A modern trend in food technologies is the development of alternative approaches, particularly the production of foods with enhanced nutritional value, including health-promoting flour confectionery products capable of positively influencing metabolic processes, stimulating the body's protective functions, and satisfying

[1] Губська О. Ю., Денесюк О. Р. Целіакія: фокус на прихильність до безглютенової дієти. Аналітичний огляд літератури. *Сучасні аспекти військової медицини. Current Aspects of Military Medicine*. 2022. № 29. С. 54–69 https://doi.org/10.32751/2310-4910-2022-29-5

the needs of people with special dietary requirements, including individuals with celiac disease and gluten intolerance.

The development of innovative technologies for flour confectionery products has been studied by domestic and foreign researchers, including A. M. Dorokhovych, V. V. Dorokhovych, V. I. Drobot, M. F. Kravchenko, M. I. Nazar, O. V. Samokhvalova, N. I. Cherevychna, A. M. Chuiko, O. H. Shydakova-Kameniuka, Arogba Sunday S., Haq Anwarul, and Camille Boucher.

Flour confectionery products, particularly sponge and choux products, account for more than 10% of the flour confectionery market and possess high sensory qualities; however, they are characterized by high contents of sugar and fat. The main formulation component of traditional products is premium wheat flour containing gluten, during the production of which the outer grain shell rich in vitamins, minerals, and dietary fiber is removed. This limits the consumption of such products by people with celiac disease and reduces their nutritional value for the general population.

The search for alternative domestic raw materials that are natural sources of biologically active substances and capable of positively affecting the human body, while also enabling the production of gluten-free products, is highly relevant. Such raw materials include:

– *"Zdorovia" flour*, produced from grain germinated in a sea salt solution containing a wide spectrum of macro- and micronutrients, including organic iodine [2];

– *carob powder*, obtained from carob tree pods as a cocoa substitute, allowing reduction of sugar content and glycemic index in finished products;

– *rice flour*, a gluten-free alternative to wheat flour rich in carbohydrates, with low fat content and high digestibility;

– *other gluten-free flours* (buckwheat, corn, sorghum, amaranth), enabling the production of products for people with celiac disease.

The gluten-free products market in Ukraine is currently developing and is mainly represented by imported products. Domestic manufacturers predominantly belong to the small business sector, and only nine Ukrainian companies possess the "Crossed Grain" gluten-free certification mark. Therefore, the development of national production of gluten-free products and foods with enhanced nutritional value is essential to meet growing consumer demand[3].

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[2] Криворучко М. Ю. Технологія борошняних кулінарних виробів на основі пророщеного зерна пшениці : автореф. дис. ... канд. техн. наук : 05.18.16. Київ. нац. торг.-екон. ун-т. Київ, 2014. 21 с.

[3] Ринок безглютенових продуктів: великий потенціал поки ще сплячої потреби. URL: https://agravery.com/uk/posts/show/rinok-bezglutenovihproduktiv-velikij-potencial-poki-se-splacoi-potrebi

The development of technologies for health-promoting flour confectionery products using germinated wheat flour, carob powder, rice flour, and other gluten-free flours requires studying their technological properties, substantiating rational concentrations, and determining their influence on the quality of finished products.

Considering the above, scientific substantiation and development of technologies for flour confectionery products with enhanced nutritional value and specialized gluten-free products constitute an important scientific task.

1. Scientific substantiation and development of technologies for flour confectionery products based on alternative raw materials

The health status of the Ukrainian population is closely related to nutrition, which currently requires significant correction and improvement. Modern global changes, rapid urbanization, and the war in Ukraine have substantially affected every citizen. In particular, military actions have caused physical and psychological stress, depression, changes in eating habits, and a general deterioration in public health[4].

In order to improve nutrition and public health, researchers are developing innovative food technologies and enhancing the nutrient composition of traditional flour confectionery products, especially sponge and choux pastry products, while also creating gluten-free alternatives for individuals with celiac disease[5].

Traditional flour confectionery products contain high amounts of sugar and flour and may also include starch, cocoa powder, and dairy ingredients. Therefore, the production of flour confectionery products involves solving several important technological and nutritional issues related to:

– increasing nutritional value;
– developing gluten-free alternatives for individuals with celiac disease;
– using raw materials possessing a wide range of technological properties;
– improving organoleptic and structural-mechanical characteristics;
– intensifying technological processes;
– extending shelf life;
– reducing the glycemic index of products.

A promising direction for expanding the assortment of nutritionally enriched flour confectionery products is the incorporation of alternative types of flour alongside or instead of wheat flour. These include amaranth, buckwheat, rice, corn (including extruded corn flour), sorghum, barley, rye, and flour

[4] Непереносимість глютену: причини та корисні поради. URL: https://apteka.net.ua/articles/neperenosymist–hlyutenu–prychyny–ta–korysni–porady

[5] Губська О. Г. Целіакія. Про проблеми діагностики і лікування цієї хвороби в Україні. *Харчова та переробна промисловість*. 2008. № 7. С. 24–26.

produced from germinated grains. Such ingredients make it possible to create new products with improved chemical composition and gluten-free products intended for specialized nutrition [6, 7, 8, 9].

The analysis of scientific literature and patent sources demonstrates that both in Ukraine and abroad, germinated grains and flour derived from them, as well as gluten-free flour types, are widely used in various sectors of food production. Grain germination enables manufacturers to obtain raw materials or ready-to-consume products with improved consumer properties. The use of alternative flour types contributes to enhanced nutritional value and broadens the assortment of health-promoting flour confectionery products [10, 11, 12, 13, 14].

One of the plant-based ingredients commonly included in confectionery formulations is cocoa powder. According to the Order "On Approval of Requirements for Cocoa and Chocolate Products", cocoa powder is defined as a food product obtained by grinding roasted cocoa beans from cocoa shells into powder, containing not less than 20% cocoa butter on a dry matter basis and not more than 9% moisture.

In confectionery technology, not only the fat content but also the color of cocoa powder plays an important role. To improve flavor characteristics and solubility in food products, cocoa nibs are treated with steam, sugar solutions, enzymes, organic acids, whey, or alkaline solutions, followed by roasting. Such cocoa powder is referred to as alkalized cocoa powder. However, during processing cocoa loses a considerable amount of biologically active substances, including vitamins, minerals, and polyphenolic compounds.

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[6] Одарченко Д. М., Карбівнича Т. В., Сподар К. В. Розширення асортименту безглютенових борошняних кондитерських виробів та оцінка їх якості. *Таврійський науковий вісник. Серія : Технічні науки*. 2024. (1), 138–144. https://doi.org/10.32782/tnv-tech.2024.1.16

[7] Рибалка О. І. Якість пшениці і її поліпшення. Одеса, 2011. С. 363–422.

[8] Carmen Rodriguez, J. Nana Frias. Correlations between some nitrogen fractions, lysine, histidine, tyrosine, and ornithine contents during the germination of peas, beans, and lentils. *Food Chemistry*, 2008. Vol. 108. Is. 1. Pp. 245–252.

[9] Influence of soya bean preparations and reduced salt content on the quality of poultry sausages / D. Grochaalska, J. Mroczek. *Medycyna weterynaryjna*. 2001. V. 57 (1). P. 54–58.

[10] Патент на корисну модель. Суміш для дитячого харчування / Соболь М. І., Терлецька В. А., Зінченко І. М., Ковбаса В. М. № 97565; заявл. 05.09.2014, опубл. 25.03.2015, Бюл. № 6.

[11] Здобне печиво з використанням борошна з пророщених зерен вівса та пшениці / В. Оболкіна, Н. Ємельянова, А. Скрипко. *Продовольча індустрія АПК*. 2014. № 2. С. 28–32.

[12] Wpływ jonów Fe2+ działający chnakiełku jącenasionasoi, lucernyo razziarni akipszeni cynazawartość skrobiic ukrówredukujących / M. Zielińska-Dawidziak, D. Piasecka-Kwiatkowska, T. Twardowski. *NaukaPrzyr. Technol*. 2010. No. 4 (2). Pp. 1–8, ISSN 1897-7820.

[13] Вплив плазмо-хімічно-активованої води на фізіологічну повноцінність зерна пшениці для виробництва цільнозернових продуктів / С. Ю. Миколенко, О. А. Пивоваров, Ю. О. Чурсінов, В. Ю. Соколов. *Вісник Дніпропетровського державного аграрно-економічного університету*. 2016. № 1. С. 57–63.

[14] Біотехнологічні методи обробки зерна з метою покращення його поживної цінності / С. М. Кудашев, Г. Д. Лукіна. *Наукові праці ОНАХТ*. 2010. Вип. 38 (1). С. 109–112.

From an economic perspective (the cost of 1 kg of cocoa powder reached 939 UAH as of April 2026), it is advisable to propose cocoa substitutes capable of matching the physicochemical properties and nutritional value of the original product while reducing production costs.

A promising substitute for cocoa powder is carob powder marketed under the trade name *carob*. Cocoa powder is approximately three times more expensive than carob powder, the production cost of which was 129.92 UAH as of May 2026. The carob tree (*Ceratonia siliqua*) is cultivated mainly in Mediterranean countries.

The chemical composition of carob powder depends on the cultivar, geographical origin, and harvesting time of the carob pods. Carob pods contain a high amount of sugars (48–56%), mainly sucrose, glucose, fructose, and maltose. In addition, the pods contain approximately 18% cellulose and hemicellulose, 3–4% protein, 0.4–0.8% lipids, and 16–20% tannins[15].

The increasing demand for gluten-free products is explained not only by the dietary needs of people with gluten intolerance but also by growing public awareness of this issue. Since a gluten-free diet remains the only effective treatment for celiac disease, the demand for gluten-free products in the Ukrainian market continues to increase[16].

Researchers are actively working on expanding the assortment of gluten-free flour confectionery products. Proposed innovative technologies include the production of various confectionery items such as sugar cookies, cakes, muffins, sponge cakes, gingerbread, and waffles using gluten-free flour types including rice, buckwheat, corn, soy, amaranth, and sorghum flour. This contributes to the development of products that meet the requirements of specialized diets and are suitable for consumers with gluten intolerance and celiac disease [17, 18, 19, 20, 21].

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[15] Ait Chitt M., Belmir,H. & Lazrak A. Production de plants sélectionnés et greffés de caroubier, In Bulletin mensuel d'information et de liaison du Pntta mapm/derd, 2007. 153, 1–4.

[16] Горбатенко І. А., Чорна Н. В. Перспективи розширення асортименту борошняних кондитерських виробів для хворих на целіакію. Матеріали Всеукраїнської науково-практичної конференції здобувачів вищої освіти і молодих учених *«Інноваційні технології розвитку у сфері харчових виробництв, готельно-ресторанного бізнесу, економіки та підприємництва: наукові пошуки молоді»*. 8 квітня 2021 р. Ч. 1. С. 7.

[17] Дорохович В. В. Безглютенові борошняні кондитерські вироби / В. В. Дорохович, Н. П. Лазоренко. *Обладнання та технології харчових виробництв*. 2013. Вип. 30. С. 341–347.

[18] Безглютеновий кекс «Гречано-сочевичний»: пат. 06279 Україна : МПК A23G3/36, № 141596; заявл. 05.06.2019; опубл. 27.04.2020, Бюл. № 15.

[19] Безглютеновий кекс спеціального призначення «Особливий»: пат. 07230 Україна : МПК A23G3/48, № 129878; заявл. 26.06.2018; опубл. 12.11.2018, Бюл. № 21. 5 с.

[20] Кекс безглютеновий: пат. 04459 Україна : МПК A21D8/00, № 138245; заявл. 24.04.2019; опубл. 25.11.2019, Бюл. № 22. 4 с

[21] Кекс шоколадний безглютеновий: пат. 02694 Україна : МПК A21D13/047, № 144562; заявл. 04.05.2020; опубл. 12.10.2020, Бюл. № 19. 4 с.

1.1. Technology of sponge cake semi-finished products based on flour blends with enhanced nutritional value

Based on the conducted analytical review of scientific and patent literature, it was established that *"Zdorovia" flour* (ZF) and carob powder (CP) possess high nutritional value due to their elevated content of proteins, dietary fiber, vitamins, and mineral compounds.

To substantiate the feasibility of using ZF and carob powder in sponge cake technology, it was considered appropriate to investigate the microstructure and rheological properties of sponge batter, as well as to determine rational technological parameters for producing sponge cake products using flour blends consisting of premium wheat flour (PWF), *"Zdorovia" flour*, and carob powder.

Sponge batter belongs to polyphase dispersed systems and represents a foam-like structure with an air-dispersed phase and a liquid dispersion medium. The dispersion medium of sponge batter is a complex heterogeneous emulsion system consisting of solutions of high-molecular compounds (egg white proteins and swollen flour colloids) and low-molecular compounds (sucrose and mineral substances of flour), emulsified egg yolk fat, and insoluble starch granules.

Flour blends were prepared using premium wheat flour and *"Zdorovia" flour* at concentrations ranging from 10% to 50%, with carob powder used as a complete substitute for cocoa powder. In experimental samples containing 10–50% ZF, the sponge batter volume increased by 0.6–6.3%; density decreased from 0.463 to 0.375 kg/m³; stability increased from 11.4×10^3 s to 19.2×10^3 s; and effective viscosity decreased by 1–18.3% compared to the control sample.

The dependence of the effective viscosity of sponge batter on shear rate within the range of 0.167 s^{-1} to 24.3 s^{-1} was investigated. It was established that intensive structural breakdown of the control sample occurred at a shear rate of 4.5 s^{-1}, whereas in experimental samples this process began at 8.1 s^{-1}. At a shear rate of 24.3 s^{-1}, the effective viscosity stabilized and amounted to 3.00 Pa·s for the control sample and 2.97–2.45 Pa·s for the experimental samples. These results indicate the resistance of sponge batter based on flour blends to mechanical destruction during mixing, pouring into molds, and the initial stage of baking.

The decrease in density and effective viscosity together with increased stability of the experimental samples contributed to improved quality characteristics of the baked sponge semi-finished products (Table 1).

Optimization of the formulation composition based on the criteria of effective viscosity, stability, and specific volume of sponge batter allowed

Table 1

Rheological and Physicochemical Properties of Sponge Batter

Flour blends (PWF:ZF)	Density, kg/m³	Effective viscosity, Pa·s	Whipping capacity, %	Volume, cm³/g	Stability, s·10³
100:0 (control)	0.481±0.04	3.00±0.09	148±0.2	220±0.05	9.0±0.5
90:10	0.463±0.02	2.97±0.48	149±0.3	222±0.15	11.4±0.6
80:20	0.445±0.001	2.81±1.03	151±0.6	225±0.45	13.8±0.27
70:30	0.426±0.02	2.76±1.2	153±0.9	230±0.95	14.7±0.56
60:40	0.398±0.05	2.55±1.41	155±0.11	234±0.14	16.2±0.73
50:50	0.375±0.07	2.45±1.61	158±0.12	235±0.15	19.2±0.8

determination of the rational ratio of premium wheat flour (PWF), *"Zdorovia" flour* (ZF), and carob powder (CP) as 3.5:1.5:1.

Rheological studies of sponge batter demonstrated that in the experimental sample containing 30% ZF, effective viscosity decreased by 8%, whereas whipping capacity increased by 3.4% and stability increased by 63.3% compared to the control sample. Regularities in the formation of quality indicators of sponge batter containing *"Zdorovia" flour* were established due to the reduction of viscosity characteristics and the increase in porosity, stability, and specific volume of sponge products. This indicates improvement of structural and mechanical properties caused by reduced gluten protein content and increased dextrin concentration.

Due to the uniform distribution of air bubbles, which form the porous structure of sponge cakes during baking, the height of experimental samples was nearly 30% greater than that of the control samples. Moreover, the temperature inside the baked sponge semi-finished product (92–95 °C) was reached almost three minutes faster than in the control sample.

Sponge batter represents a weakly structured foam system consisting of a dispersion medium and a dispersed phase in the form of air bubbles. In the control sample, the dispersion medium was dominated by starch paste, whereas in the experimental sample soluble dextrins predominated. Such a medium creates favorable conditions for the uniform distribution and formation of smaller air bubbles compared to the control sample, which in turn affects important physicochemical indicators such as volume, density, effective viscosity, and stability of sponge batter.

Dextrinized starch granules of *"Zdorovia" flour* contribute to stabilization of the rheological properties of sponge batter during mixing and baking, making it possible to obtain sponge products of high quality.

1.2. Prospects for the use of gluten-free flours in the technology of flour confectionery products

One of the promising directions in the development of flour confectionery products for special dietary purposes is the use of gluten-free flours, in particular rice flour, which is a product of rice processing and is characterized by high nutritional value, easy digestibility, and the absence of gluten.

Rice flour is rich in carbohydrates (up to 80%), has a low fat content (less than 1%), contains B-group vitamins and minerals (potassium, magnesium, phosphorus), and is characterized by a neutral taste, which makes it a versatile ingredient for the production of gluten-free confectionery products. In addition, rice flour has a low glycemic index, making it suitable for people with diabetes and those who aim to control blood glucose levels[22].

However, the use of rice flour in flour confectionery technology has its own specific features related to the absence of gluten, which provides dough elasticity and extensibility. To compensate for the lack of gluten, it is necessary to use structure-forming additives such as:

- guar gum;
- xanthan gum;
- psyllium (plantain seed husk);
- carboxymethyl cellulose;
- pectin.

The application of these additives makes it possible to improve the rheological properties of gluten-free dough, ensuring the required viscosity, elasticity, and the ability to form a stable structure.

Many domestic and foreign researchers are working on improving the technology of gluten-free cookies, cupcakes, and sponge cakes with the addition of guar gum and xanthan gum to enhance the properties of gluten-free dough made from rice, corn, and buckwheat flour. Studies show that one of the ways to expand the assortment of gluten-free confectionery products based on sponge cake systems is the use of sorghum flour, which is rich in dietary fiber, antioxidants, B-group vitamins, phosphorus, and plant fats beneficial for cardiovascular health.

Expanding the range of gluten-free flour confectionery products is an important step in the development of national food production. Patented utility models such as “Gluten-Free Chocolate Cupcake” and “Gluten-Free Cupcake”, which use corn and rice flour instead of traditional wheat flour,

[22] Дорохович В. В. Безглютенові борошняні кондитерські вироби / В. В. Дорохович, Н. П. Лазоренко. *Обладнання та технології харчових виробництв*. 2013. Вип. 30. С. 341–347.

contribute to the creation of safe and high-quality alternatives for people with celiac disease [23, 24].

In addition, gluten-free cupcakes for special dietary purposes have been developed, such as the "Special" cupcake with puree from sprouted mung beans, and the "Buckwheat–Lentil" cupcake, which is characterized by increased nutritional and biological value, has a low glycemic index, and is completely gluten-free, making it recommended for people following a gluten-free diet[25, 26].

Thus, the use of gluten-free flours opens up broad opportunities for the creation of innovative flour confectionery products that meet the needs of various consumer groups – from individuals with celiac disease to those who aim to maintain a healthy lifestyle and control the glycemic index of their diet.

2. Technology and quality of flour-based confectionery products of health-oriented purpose

Sponge products are characterized by a high content of carbohydrates and high energy value due to the significant proportion of premium wheat flour and sugar. Based on the obtained research results, a technology and formulation of a sponge semi-finished product were developed using BZ at a concentration of 30% and complete replacement of cocoa powder with carob powder, which serves as the basis for the production of sponge confectionery products.

When developing the formulation of sponge products, the sweetness index of carob powder (0.5) was taken into account, which made it possible to reduce the sugar content by 10%.

A formulation and technology for sponge dough were developed, which include the following stages:

– mechanical culinary processing of raw materials;

– preparation of sponge dough from a flour mixture and depositing into molds;

– baking, cooling, maturation, shaping, and finishing of baked sponge semi-finished products.

Based on the baked sponge semi-finished product, formulations of sponge confectionery products were developed: "Hutsulskyi" cake, "Zakarpatskyi" roll, "Bushe" biscuits, and "Shokoladne" pastry.

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[23] Кекс шоколадний безглютеновий: пат. 02694 Україна : МПК A21D13/047, № 144562; заявл. 04.05.2020; опубл. 12.10.2020, Бюл. № 19. 4 с.

[24] Кекс безглютеновий: пат. 04459 Україна : МПК A21D8/00, № 138245; заявл. 24.04.2019; опубл. 25.11.2019, Бюл. № 22. 4 с.

[25] Безглютеновий кекс «Гречано-сочевичний»: пат. 06279 Україна : МПК A23G3/36, № 141596; заявл. 05.06.2019; опубл. 27.04.2020, Бюл. №4.

[26] Безглютеновий кекс спеціального призначення «Особливий»: пат. 07230 Україна : МПК A23G3/48, № 129878; заявл. 26.06.2018; опубл. 12.11.2018, Бюл. № 21. 5 с.

The baked sponge semi-finished product with the flour mixture demonstrated improved porosity (71.4%), which is 2.7% higher than the control sample; the specific volume is 24.6% higher. In the baked sponge semi-finished product, the baking loss index is lower, and the staling process is slowed down (elasticity and crumbliness indicators are lower by 10.5% and 18.8% compared to the control sample) due to the high fiber content in BZ, which is capable of binding and retaining moisture more strongly, indicating improved quality of sponge products.

According to sensory evaluation results of sponge semi-finished products, a profilogram of organoleptic quality indicators was constructed, where the control sample scored 4.71 points, and the experimental sample scored 4.94 points.

Studies of the nutritional value of sponge products showed that fat content decreased by 5.2%, total carbohydrate content decreased by 7.7%, including mono- and disaccharides by 9.3% and starch by 12.4%, while dietary fiber increased by 96.9% compared to the control. The content of B-group vitamins also increased (niacin – twofold, pyridoxine – tenfold), as well as mineral elements (calcium – by 26.4%, magnesium – by 21.7%) compared to traditional sponge products. The iodine content in the experimental sample was 2.7 μg, which is 5.6 times higher than in the control. The energy value of the experimental sample decreased by 6.6%.

The glycemic index reflects the rate of carbohydrate breakdown into glucose in the blood and is an important indicator for food products intended for people with diabetes and obesity. Determination of the glycemic index of sponge products showed that it was 34.61 in the control sample and 26.20 in the experimental sample, which is 24% lower.

The baked sponge semi-finished product was stored in cardboard boxes at a temperature of 18–20 °C and relative air humidity of 70±5% for 7 days in accordance with DSTU 4460:2005. Elasticity (34.1 units), crumbliness (8.2%), and drying (3.6%) indicators were lower by 10.5%, 18.8%, and 16.3%, respectively, compared to the control sample due to the high hydrophilic capacity of BZ fiber, which confirms better storage stability.

Microbiological indicators of both control and experimental samples met the requirements of regulatory documentation. No bacteria of the Escherichia coli group, pathogenic microorganisms including Salmonella spp., as well as mold fungi and yeast were detected in the studied sponge products.

The determined toxicological indicators of the developed sponge product do not exceed permissible sanitary standards (DSTU 8001:2015), confirming the safety of the new product.

Technical specifications, technological instructions were developed for the sponge formulation with BZ and carob powder, and a utility model patent of Ukraine was obtained.

2.1. Prospects for the development of gluten-free flour-based confectionery products

The increasing number of people with gluten intolerance and celiac disease necessitates the expansion of the range of gluten-free flour-based confectionery products. One of the main methods of prevention and treatment of gluten intolerance is a gluten-free diet, which involves the exclusion of all products containing gluten from the diet, namely wheat, barley, rye, and products derived from them.

Promising directions for the development of gluten-free flour-based confectionery products include:

1) the use of rice flour in the technology of choux, sponge, and other types of dough with the addition of structure-forming agents (psyllium, guar gum, and xanthan gum);

2) the application of blends of gluten-free flours (rice, buckwheat, corn, sorghum, amaranth) to achieve an optimal balance of nutritional value and structural-mechanical properties;

3) the inclusion of functional ingredients such as sprouted grains, chia seeds, and flax seeds, which increase the content of protein, dietary fiber, and omega-3 fatty acids;

4) the use of natural sugar substitutes (stevia, erythritol) to reduce the glycemic index and caloric content of products;

5) the development of combined technologies that integrate health-promoting and gluten-free properties of products.

An important aspect is ensuring high organoleptic qualities of gluten-free products, since the absence of gluten can negatively affect texture, volume, and taste characteristics. The use of integrated technological solutions makes it possible to produce gluten-free flour-based confectionery products that are not inferior in quality to traditional analogues.

The gluten-free product market in Ukraine has significant development potential. Increasing public awareness of celiac disease and gluten intolerance, growing demand for health-oriented food products, as well as state support for producers of specialized foods create favorable conditions for the implementation of innovative technologies in gluten-free flour-based confectionery production.

CONCLUSIONS

Based on the analysis of the domestic market of flour-based confectionery products, theoretical studies, as well as scientific and patent sources, the feasibility of using flour from germinated wheat grain, carob powder, and gluten-free flour types in flour blends in the technology of flour-based confectionery products has been substantiated. This approach is aimed at improving their nutritional value, reducing the glycemic index, and creating products for individuals with celiac disease, which will contribute to expanding the range of health-oriented food products.

The feasibility and potential of using flour from germinated wheat grain and carob powder in flour blends have been justified. The rational ratio of formulation components in flour blends BPVS:BZ:CP was established as 3.5:1.5:1, under which sponge dough is formed with physicochemical and rheological characteristics (effective viscosity 2.76 Pa·s, stability 14.7 $s \cdot 10^3$, volume 158%) close to those of traditional dough.

The microstructure of sponge dough was studied, and it was found that in the experimental sample, due to a decrease in effective viscosity (by 8%), a more uniform distribution and formation of smaller air bubbles occurred compared to the control sample. This contributed to an increase in volume and allowed for the prediction of improved structural and mechanical properties of the baked sponge semi-finished products.

A scientifically grounded technology of sponge cakes based on flour blends was developed. The following physicochemical indicators were determined: baking loss, elasticity, and crumbliness decreased by 11%, 6%, and 50%, respectively, while specific volume and porosity increased by 2.7% and 4.3%, indicating improved quality. The glycemic index decreased by 24%.

The quality of sponge products was assessed based on chemical composition: fat content decreased by 5.2%, total carbohydrates by 7.7%, including mono- and disaccharides by 9.3% and starch by 12.4%, while dietary fiber increased by 96.9% compared to the control. The content of B-group vitamins increased (niacin – twofold, pyridoxine – tenfold), as well as mineral elements (calcium – by 26.4%, magnesium – by 21.7%) compared to traditional products. The iodine content in the experimental sample was 2.7 μg, which is 5.6 times higher than in the control; the energy value decreased by 6.6%.

Changes in product quality during storage were studied: elasticity (34.1 conventional units), crumbliness (8.2%), and shrinkage (3.6%) were lower by 10.5%, 18.8%, and 16.3%, respectively, compared to the control sample, indicating better storage stability and slower staling processes due to the higher fiber content in the “Zdorovia” flour, which has high water-holding capacity.

Microbiological and toxicological indicators of the developed sponge products did not exceed established safety standards. No bacteria of the Escherichia coli group, pathogenic microorganisms including Salmonella spp., as well as mold fungi and yeast were detected.

The prospects of using gluten-free flour types (rice, buckwheat, corn, sorghum) in the technology of special-purpose flour-based confectionery products for individuals with celiac disease and gluten intolerance were analyzed. The necessity of using structure-forming additives to compensate for the absence of gluten was identified.

The economic efficiency of implementing the developed sponge technologies was determined, achieved through a reduction in production cost by an average of up to 10%, lower energy consumption, reduced sugar content in formulations, and the use of carob instead of cocoa.

The social effect lies in expanding the range of flour-based confectionery products with improved nutritional value, reduced glycemic index, and gluten-free formulations for special dietary purposes. This will contribute to improving the dietary structure of the population of Ukraine, particularly individuals with celiac disease and gluten intolerance.

SUMMARY

Based on an analytical review of domestic and foreign literature, the feasibility of using “Zdorovia” flour, carob powder, and gluten-free flour types in the technology of health-oriented flour-based confectionery products has been substantiated.

The rheological properties of sponge dough were investigated, and the physicochemical and microbiological characteristics of baked sponge semi-finished products produced with “Zdorovia” flour and carob powder were determined. The prospects of using rice and other gluten-free flour types for the development of health-oriented products were analyzed.

A technology was developed, and a comprehensive quality assessment of sponge confectionery products with enhanced nutritional value was carried out. Regulatory documentation for the new sponge products was approved, and the products have been implemented in food service establishments. The prospects for creating gluten-free flour-based confectionery products for individuals with celiac disease and gluten intolerance have been substantiated.

Bibliography

1. Губська О. Ю., Денесюк О. Р. Целіакія: фокус на прихильність до безглютенової дієти. Аналітичний огляд літератури. *Сучасні аспекти*

військової медицини. Current Aspects of Military Medicine. 2022. № 29. С. 54–69. https://doi.org/10.32751/2310-4910-2022-29-5

2. The influence of gluten-free flours on the quality indicators of biscuit semi-finished products / K. Iorgachova, O. Makarova, E. Kotuzaki. *Зернові продукти і комбікорми*. Одеса. 2016. Vol. 64, Issue 4. P. 16–21.

3. Криворучко М. Ю. Технологія борошняних кулінарних виробів на основі пророщеного зерна пшениці : автореф. дис. ... канд. техн. наук : 05.18.16. Київ. нац. торг.-екон. ун-т. Київ, 2014. 21 с.

4. Ринок безглютенових продуктів: великий потенціал поки ще сплячої потреби. URL: https://agravery.com/uk/posts/show/rinok-bezglutenovihproduktiv-velikij-potencial-poki-se-splacoi-potrebi

5. Непереносимість глютену: причини та корисні поради. URL: https://apteka.net.ua/articles/neperenosymist–hlyutenu–prychyny–ta–korysni–porady

6. Губська О. Г. Целіакія. Про проблеми діагностики і лікування цієї хвороби в Україні. *Харчова та переробна промисловість*. 2008. № 7. С. 24–26.

7. Одарченко Д. М., Карбівнича Т. В., Сподар К. В. Розширення асортименту безглютенових борошняних кондитерських виробів та оцінка їх якості. *Таврійський науковий вісник. Серія : Технічні науки*. 2024. (1), 138–144. https://doi.org/10.32782/tnv-tech.2024.1.16

8. Рибалка О. І. Якість пшениці і її поліпшення. Одеса, 2011. С. 363–422.

9. Carmen Rodriguez, J. Nana Frias. Correlations between some nitrogen fractions, lysine, histidine, tyrosine, and ornithine contents during the germination of peas, beans, and lentils. *Food Chemistry*, 2008. Vol. 108. Is. 1. Pp. 245–252.

10. Influence of soya bean preparations and reduced salt content on the quality of poultry sausages / D. Grochaalska, J. Mroczek. *Medycyna weterynaryjna.* 2001. V. 57 (1). P. 54–58.

11. Патент на корисну модель. Суміш для дитячого харчування / Соболь М. І., Терлецька В. А., Зінченко І. М., Ковбаса В. М. № 97565; заявл. 05.09.2014, опубл. 25.03.2015, Бюл. № 6.

12. Здобне печиво з використанням борошна з пророщених зерен вівса та пшениці / В. Оболкіна, Н. Ємельянова, А. Скрипко. *Продовольча індустрія АПК*. 2014. № 2. С. 28–32.

13. Wpływ jonów Fe2+ działający chnakiełku jącenasionasoi, lucernyo razziarni akipszeni cynazawartość skrobiic ukrówredukujących / M. Zielińska-Dawidziak, D. Piasecka-Kwiatkowska, T. Twardowski. *NaukaPrzyr. Technol*. 2010. No. 4 (2). Pp. 1–8, ISSN 1897-7820.

14. Вплив плазмо-хімічно-активованої води на фізіологічну повноцінність зерна пшениці для виробництва цільнозернових продуктів / С. Ю. Миколенко, О. А. Пивоваров, Ю. О. Чурсінов, В. Ю. Соколов. *Вісник Дніпропетровського державного аграрно-економічного університету*. 2016. № 1. С. 57–63.

15. Біотехнологічні методи обробки зерна з метою покращення його поживної цінності / С. М. Кудашев, Г. Д. Лукіна. *Наукові праці ОНАХТ*. 2010. Вип. 38 (1). С. 109–112.

16. Ait Chitt M., Belmir H. & Lazrak A. Production de plants sélectionnés et greffés de caroubier, In Bulletin mensuel d'information et de liaison du Pntta mapm/derd, 2007. 153, 1–4.

17. Горбатенко І. А., Чорна Н. В. Перспективи розширення асортименту борошняних кондитерських виробів для хворих на целіакію. Матеріали Всеукраїнської науково-практичної конференції здобувачів вищої освіти і молодих учених *«Інноваційні технології розвитку у сфері харчових виробництв, готельно-ресторанного бізнесу, економіки та підприємництва: наукові пошуки молоді».* 8 квітня 2021 р. Ч. 1. С. 7.

18. Дорохович В. В. Безглютенові борошняні кондитерські вироби / В. В. Дорохович, Н. П. Лазоренко. *Обладнання та технології харчових виробництв*. 2013. Вип. 30. С. 341–347.

19. Безглютеновий кекс «Гречано-сочевичний»: пат. 06279 Україна : МПК A23G3/36, № 141596; заявл. 05.06.2019; опубл. 27.04.2020, Бюл. № 15.

20. Безглютеновий кекс спеціального призначення «Особливий»: пат. 07230 Україна : МПК A23G3/48, № 129878; заявл. 26.06.2018; опубл. 12.11.2018, Бюл. № 21. 5 с.

21. Кекс безглютеновий: пат. 04459 Україна : МПК A21D8/00, № 138245; заявл. 24.04.2019; опубл. 25.11.2019, Бюл. № 22. 4 с

22. Кекс шоколадний безглютеновий: пат. 02694 Україна : МПК A21D13/047, № 144562; заявл. 04.05.2020; опубл. 12.10.2020, Бюл. № 19. 4 с.

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