The use of non-traditional types of flour in the production of gluten-free butter cookies

Alexey Belyaev[1*], *Olga* Shvets[2], and *Irina* Belyaeva[1]

[1]South-Western State University, 94, 50 Let Oktyabrya str., Kursk, 305040, Russian Federation
[2] Kursk State Agrarian University named after I. I. Ivanov, 70, Karl Marx Street, Kursk, 305021, Russian Federation

Abstract. This study investigates the potential of using rice, corn, and millet flour, as well as burdock root flour, as a fortifying additive in the production of gluten-free butter cookies. The control sample was a classic butter cookie recipe using a gluten-free mixture of rice, corn, and millet flour. Burdock root flour was added in varying proportions (5%, 10%, 15%) to the remaining recipe components, replacing them. The samples were evaluated based on physical and chemical indicators, including ash content, alkalinity, moisture content, wettability, and iron content. Organoleptic properties were also considered. The results showed an increase in iron and ash content compared to the control sample. Sample 3 was found to be the most successful based on physical and chemical indicators, while sample 1 was the best according to organoleptic indicators.

1 Introduction

Recently, the demand for gluten-free products such as bakery and confectionery products with similar nutritional and taste characteristics to partially replace traditional cereal-based products has increased significantly. This demand was driven by an increase in the number of patients suffering from celiac disease, an immunopathology that leads to a negative reaction when consuming gluten-containing products in people intolerant to gluten. Foods made from wheat, rye, barley and oats contain gluten and can harm the health of these people by causing inflammation and damage to the lining of the small intestine.

This work explored the use of various components, including rice, corn, millet flour, and burdock root flour, as fortifying additives in the preparation of gluten-free cookies. The study examined the impact of these additives on the quality characteristics of the resulting samples, focusing on physicochemical parameters such as ash mass fraction, alkalinity, moisture content, wettability, and iron content. Additionally, the organoleptic properties of the samples were evaluated.

A study by Hamida Banu Itagi et al. focused on the use of two “traditional Indian rice varieties, Kalanamak and Chak Khao, in the production of whole grain gluten-free biscuits fortified with bioactive compounds.” The study also examined the effects of whole grain rice flour and various sweeteners on the properties of the cookies. Replacing refined wheat flour

* Corresponding author: 7631pektin@mail.ru

with rice flour significantly changed the physical and chemical characteristics of the biscuits [1].

Research data from Linda Schmelter, Harald Rohm and Susanne Struck from the Technical University of Dresden, Department of Food Engineering, reports the results of studies on the use of flour obtained from six different varieties of beans in the production of gluten-free biscuits. Researchers have been studying the flour's potential to replace wheat flour in cookies. The high "protein and fiber content of the formulations resulted in a harder texture and darker color in the cookies." Sensory analysis showed that the type of bean significantly affects the taste and aroma of cookies [2].

Supriya Kumari and her colleagues conducted a study that examined the effect of different types of flour on the quality of gluten-free cookies. They improved the nutritional value and beneficial properties of the cookies by replacing rice flour with malted buckwheat and millet flour by 15 and 30 percent. The authors found that “the use of malt flour from all three grains increased protein content, total dietary fiber, and other characteristics of the biscuits.” These results support the usefulness of malt flour for improving the composition of gluten-free rice biscuits [3]. Research by Carla M. Jofre and her colleagues has shown that flour from grape waste can be used to create gluten-free cookies. The study found that “cookies and grape flour filling contain more protein, vegetable fat and fiber than regular cookies.” Moreover, the new product was well received when tested for taste and smell [4].

A review by Adebola O. Oladunjoye and Adeola E. Alade describes a study on the quality characteristics of gluten-free biscuits made “from sorghum flour and tigernut marc.” Flour mixtures containing 0 to 20% sorghum were studied for functional and textural properties of the dough, and biscuits for immediate, physical, bioactive, microbial and sensory properties. The researchers concluded that “the organoleptic properties of cookies with the addition of these ingredients were higher than those of the sample without them.” They found that the use of these additives as a functional ingredient in gluten-free cookies is technically feasible, which is especially valuable for people suffering from celiac disease [5]. Researchers Taisa M.A. Moreau, Maria T.P.S. Clerici provided data on the study of such raw materials as burdock root, indicating the potential of burdock roots as “a source of prebiotic fibers, chlorogenic acids, cinnarine, lignans and quercetin” [6]. The promise of using burdock roots as an additive to product formulations and as an independent product has also been shown in other studies. Thaisa Menezes Alves Moroa and co-authors propose “the use of burdock root flour as a prebiotic ingredient in cookies” [7]. Sergey Boev and co-authors provide data on the study of the use of burdock root components in the production of gluten-free bread, without adding sugar to the recipe, and the study of its sensory indicators [8].

Alexander Kaluzhskikh suggests using mushrooms as an additive in the production of bread [9]. Millet or millet flour is also being studied by researchers to determine the possibility of its use in the production of bakery products. Bushra Siddiqa and co-authors from Henan University of Technology studied "the effect of adding millet flour (ranging from 0% to 50%) on the rheological, textural and water movement characteristics of wheat dough, as well as the quality of chapatis." The researchers concluded that “the addition of millet flour to wheat flour showed promise in producing high-quality and nutritious chapatis by improving dough rheology, dough strength, and improved chewiness.” The authors' study provides "valuable information for the food industry to optimize the formulation of healthier and more desirable chapati products" with millet flour added to the formulations [10]. Researchers from Brazil, Jacqueline Maciel Vieira Teodoro and co-authors, conducted studies to comparatively evaluate the effects of regular and sprouted millet flour “on iron metabolism and antioxidant capacity in rats” [11]. “Iron deficiency is a nutrition-related health problem that can lead to iron deficiency anemia, a disease that affects more than 2 billion people in low-, middle- and high-income populations worldwide, leading to increased morbidity and mortality " [eleven]. The researchers determined that "millet provides

promising iron bioavailability." In addition, sprouted millet is characterized by improved iron metabolism and antioxidant capacity similar to regular millet.

V. Okwunodulu and the co-authors from the Agricultural University of Nigeria conducted the study. which "aimed at the development and analysis of gluten-free sourdough bread made from blended millet, bambara nut and pearl millet flours and soybeans and compared with bread made from wheat flour" [12]. The authors obtained the best results when using millet flour and bambara nuts 50/50 [12]. Supriya Kumari and co-authors from Guru Nanak Dev University of India, Amritsar proposed "the preparation of gluten-free biscuits with improved nutritional value and health benefits." The researchers replaced some of the rice flour with malt, buckwheat and millet flour. Malt flour was obtained after germination. The authors concluded that the studied components can be included in rice cookies to improve nutritional and functional properties [13]. Oluwatoyin O. Onipe and co-authors from the University of Venda, South Africa, report on studies of a mixture of finger millet flour with local African fruit tree flour. "Finger millet is an underutilized crop and is rich in macronutrients (potassium, niacin, calcium, phosphorus and iron), containing high amounts of calcium compared to other crops such as wheat, rice, corn, sorghum and barley." Researchers have successfully used this flour mixture to produce cookies with beneficial properties [14]. When studying the issue under consideration about the properties of the ingredients included in gluten-free cookies, no data was found on the study of such an additive in cookies as burdock root flour.

The purpose of the study was to determine the possibility of using components from rice, corn and millet flour, as well as burdock root flour as a fortifying additive. in the production of gluten-free butter cookies and their influence on the quality indicators of the obtained samples.

The study outlined tasks such as the selection of formulation components to create new types of gluten-free butter cookies obtained with the addition of various concentrations of burdock root flour, and the addition of millet flour to the recipes.

Samples of the resulting product were examined for quality indicators, and the best samples were identified, combining good organoleptic characteristics and benefits for the body.

2 Materials and methods

2.1 Materials

The following recipe components were used for the research: rice, corn, millet flour, burdock root flour, granulated sugar, chicken eggs, butter. Dried burdock root was ground in a laboratory mill to obtain flour.

2.2 Recipes of the samples under study

The raw materials and recipes of the obtained samples are given in Table 1.

Table 1. Recipes for prototypes of gluten-free cookies.

Raw material composition	Control sample	Sample No.1	Sample No.2	Sample No.3
Rice flour, g	75	71	67	63
Millet flour, g	75	71	67	63
Corn flour, g	50	47	45	42

Granulated sugar, g	80	80	80	80
Eggs, pcs.	2	2	2	2
Butter, g	100	100	100	100
Burdock root flour, g	-	10	18	26

Burdock root flour was added to the recipe of the butter cookie samples, and a gluten-free mixture of three types of flour was used: millet, rice, corn, to enrich the gluten-free cookies. Burdock root flour was added in amounts of 5, 10, 15% to the weight of the gluten-free mixture of three types of flour directly during kneading and other components.

2.3 Sample manufacturing technology

The raw materials were prepared, the dough was kneaded, dough pieces were formed and cookies were baked. To prepare the dough, beat the butter for 5–10 minutes until the volume increases, then, without stopping churning, gradually add sugar, the resulting mixture is whipped for 3–5 minutes, the pre-cooled and whipped protein is added, the mixture is stirred for 1–2 minutes to to achieve a homogeneous state, after which the dry mixture from the recipe components indicated in (Table 1) was gradually added, the dough was kneaded for 3–5 minutes, at slow speeds until smooth, after which the dough was formed by depositing onto baking sheets, which were then placed in oven, baking of dough pieces was carried out at a temperature of 180–190°C for 10–15 minutes.

2.4 Physico-chemical parameters of samples

The ash mass fraction, moisture mass fraction, alkalinity, and wettability of the samples were determined after manufacture by following the methods outlined in the AOAC INTERNATIONAL Official Methods of Analysis (OMA). Additionally, the iron content in food products was determined using a spectrophotometer, which measured the color intensity of a solution of a complex compound of divalent iron with orthophenanthroline after preliminary dry mineralization of the samples.

2.5 Organoleptic characteristics of samples

Gluten-free cookies must meet the requirements specified in Table 2 in terms of organoleptic indicators. The assessment of the organoleptic properties of the samples was carried out using experts and organoleptic methods [15]. According to the organoleptic indicators, the cookies must meet the requirements outlined in Table 2.

Table 2. 2.5 Organoleptic characteristics of cookies.

Indicators	Characteristics of cookies
Taste and smell	Pronounced, characteristic taste and smell of the components included in the cookie recipe, without extraneous taste and smell
Form	Varied, not blurry, no dents, blisters or edge damage
Surface	Smooth or rough
Color	Uniform, from light straw to dark brown, depending on the raw materials used. Darker coloring is allowed for the protruding parts of the relief pattern, the edges of the cookies,

	the bottom side and marks from the mesh of the oven hearth.
Fractured view	Baked cookies with a porous structure, without voids or traces of unkneading.

3 Results and discussion

Based on the information presented above, an assessment was made of the organoleptic characteristics of samples of gluten-free butter cookies containing various concentrations of burdock root flour in the recipe.

Control sample 1 in Figure 1a, which is a cookie without burdock root flour, has a sweet taste characteristic of the components in the product recipe, without any foreign odors or tastes. The shape is square and not blurry, with no dents, swelling, or damage to the edges. The surface is rough, with a uniform light straw-colored color, and the baked cookies have a porous structure without voids or traces of unkneading.

Sample 2 in Figure 1b, which contains 5% burdock root flour, has a sweet taste characteristic of the components in the product recipe, with a faint taste of millet flour and burdock root. There is a faint smell of burdock and millet. The shape is square, not blurry, with no dents, swelling, or edge damage. The surface is rough, with a uniform light brown color, and the baked cookies have a porous structure without voids or traces of unkneading.

Sample 3 in Figure 1c, which contains 10% burdock root flour, has a sweet taste characteristic of the components in the product recipe, with a taste of burdock root flour and a faint taste of millet flour. There is a smell of burdock and a faint smell of millet. The shape is square, not blurry, with no dents, bulges, or edge damage. The surface is rough, with a uniform brown color, and the baked cookies have a porous structure without voids or traces of unkneading.

Sample 4 in Figure 1d, which contains 15% burdock root flour, has a sweet taste characteristic of the components in the product recipe, with a pronounced taste of burdock root flour and a weak taste of millet flour. There is a pronounced smell of burdock and a faint smell of millet. The shape is square, not fuzzy, with no dents, bulges, or edge damage. The surface is rough, with a uniform dark brown color, and the baked cookies have a porous structure without voids or traces of unkneading.

control sample No 1 a Sample No.2 b Sample No.3 c Sample No.4 d

Fig. 1. Samples of gluten-free butter cookies.

The quality of the finished buttery gluten-free cookies was assessed by several physicochemical indicators, including wetness, mass fraction of ash, mass fraction of moisture, alkalinity, and the amount of iron in the product. These indicators were determined by standard methods and comply with relevant standards.

The wetness indicator was the most significant in the control sample, measuring 219.6%. In the test samples, the wetness was lower, but there was a pattern of decreasing wetness with increasing burdock root flour in the recipes, with values of 186.1% for sample 2, 165.2% for sample 3, and 151.1% for sample 4.

The moisture content in the samples was lower compared to the control, and it decreased with increasing content of burdock root flour in the cookies. Conversely, the mass fraction of ash increased with increasing content of burdock root in the formulation.

An indicator such as alkalinity decreased with increasing content of burdock root flour in the recipe, and was the highest in the control sample that did not contain burdock root flour.

The results for wetness, mass fraction of ash, mass fraction of moisture, and alkalinity are presented in Table 3.

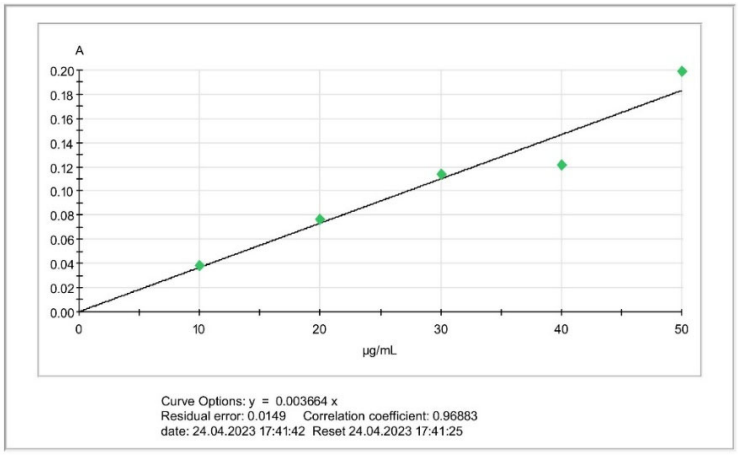
Table 3. Physico-chemical parameters of samples.

Indicator	Samples			
	Control sample 1	Sample 2	Sample 3	Sample 4
Moisture contents, %	6	3	2,5	1
Alkalinity, degree	12	5	7	3
Mass fraction of ash, %	0.073	0.079	0.080	0.085
Wetness, %	219.6	186.1	165.2	151.1

After the studies of iron in the samples, we obtained the following data presented in Figure 2, and recalculated the resulting concentration into milligrams per kilogram presented in Table 4. Data on the iron content in the studied samples are presented in Table 4.

Table 4. Iron content in the studied samples.

Sample #	Sample name	Iron content, mg/kg
#1	Control sample 1	24.425
#2	Sample 2	27.1
#3	Sample 3	27.15
#4	Sample 4	68.85



Try	Breeding Factor	Ordinate [A]	Concentration [µg/mL]
Control	1	0.036	9.77
5%	1	0.040	10.84
10%	1	0.040	10.86
15%	1	0.101	27.54

Fig. 2. Iron readings in gluten-free cookie samples.

Iron, when combined with protein, vitamins, chlorophyll, and silicic acid, enhances carbohydrate and protein metabolism. This process is accompanied by an increase in the tone of the cardiovascular, respiratory, and other body systems. Additionally, iron helps increase the hemoglobin content in the blood and the number of red blood cells. Given the daily human body requirement for iron, the most suitable cookie sample for consumption is the one with the largest amount of burdock root flour in the recipe, which replaces 15% of the gluten-free flour mixture.

4 Conclusion

As a result of the research conducted in accordance with the stated goal, the assigned tasks were solved. The effectiveness of using burdock root flour and millet flour products in the production of gluten-free cookies has been determined and proven. The effectiveness of the added additive lies in the results obtained by determining the concentration of the macroelement iron, organoleptic, and physicochemical parameters in the presented samples of gluten-free cookie products. The practical significance of the study lies in the possibility of using the results obtained in the production of gluten-free cookies. Additionally, the scientific novelty of the conducted research lies in the use of a mixture of gluten-free millet, rice, and corn flour and burdock root flour in the manufacture of cookies and the study of their quality indicators.

The evaluation of gluten-free cookies from three samples revealed that sample No. 2, with a replacement of 5% burdock root flour by weight of the gluten-free mixture, was the best in terms of organoleptic indicators. Studies were also conducted on physical and chemical indicators, and sample No. 4 was found to have the highest iron content. Sample No. 2 is the most acceptable for production, as it turned out to be the best in terms of organoleptic characteristics.

References

1. H. Banu Itagi, et al., LWT-Food Science and Technology, **186**, 115245, (2023)
2. L. Schmelter, H. Rohm, S. Struck, Future Foods, **4,** 100038, (2021)
3. S. Kumari, et al., Food Chemistry Advances, **3,** 100557, (2023)
4. C.M. Jofre, et al. Food Chemistry Advances, **4,** 100583, (2024)
5. Adebola O. Oladunjoye, Adeola E. Alade, Food Chemistry Advances, **4,** 100626, (2024)
6. T.M.A. Moro and M. T.P.S. Clerici, Food Research International, **141,** 109889, (2021)
7. T.M.A. Moro et al., LWT - Food Science and Technology, **90,** 540–546, (2018)
8. S. Boev, V. Varavin, V. Trubnikov, S. Grashkov, and D. Eskov, E3S Web of Conferences **390,** 02041, (2023)
9. A. Kaluzhskih, E. Batrachenko, M. Kotelnikova, R. Yevglevskiy, and S. Ryumshina, E3S Web of Conferences **390,** 02027, (2023)
10. B. Siddique, A. Wang, L. Wu, I. Ahmad, Food and Humanity **2,** 100249, (2024)
11. J. M. Vieira Theodoro, et al., Journal of Cereal Science, **116,** 103840, (2024)
12. I.N. Okwunodulu, G.N. Egbuta, F.U. Okwunodulu, C.M. Ojinnaka, S.C. Onyeiwu, Food Chemistry Advances **4,** 100633, (2024)
13. S. Kumari, B. Singh, A. Kaur, Food Chemistry Advances, **3,** 100557, (2023)

14. Oluwatoyin O. Onipe, Musundwa M. Matshisevhe, Shonisani E. Ramashia, Mpho E. Mashau, Scientific African, **23,** e02092, (2024).
15. E.A. Pyanikova, A.E. Kovaleva, M. A. Zaikina, and A.G. Belyaev, E3S Web of Conferences **285,** 05001, (2021)
16. L.E. Murray-Kolbe, J. Beard Iron et al., *Inform a Healthcare* (London and New York, 2010)