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LOW-GLUTEN SHORTBREAD ENRICHED WITH SWEET POTATO POWDER (*IPOMOEA BATATAS VAR. PORTU ORANGE*): QUALITY AND TEXTURE INDICATORS

The chemical composition of sweet potato (Ipomoea batatas var. Portu Orange), grown in Ukraine, was studied to determine its potential in shortbread technology. Portu Orange sweet potato has a high content of starch (11.2 %), natural sugars (4.7 %), dietary fiber (3.8 %) and food pigments. To obtain the highest quality characteristics and preserve the antioxidant properties of sweet potato during drying, an innovative microwave vacuum drying method was used. This allowed us to produce Portu Orange sweet potato powder with a high content of starch (43 %), natural sugars (18 %), dietary fibre (14.6 %) and preservation of food colouring properties. According to organoleptic parameters, Portu Orange sweet potato has an orange color, which was formed with a combination of anthocyanin pigmentation of the skin (orange) and β-carotene pigmentation of the flesh (light orange). In shortbread technology, Portu Orange sweet potato is used in powder form, which is an alternative to starch, sugar, orange food colorings, gluten-containing cereals and egg products. Portu Orange sweet potato powder was added to the shortbread recipe in the amount of 38 % to completely replace sugar and chicken eggs. The wheat flour in the recipe was replaced by 80 % low-gluten wheat flour and 20 % sweet potato powder. Compared to regular shortbread, the protein content increased by 24.3 % to 9.2 g/100 g, the dietary fiber content increased by 74.6 % to 10.3 g/100 g, and the ash content increased by 155.6 % to 2.3 g/100 g. The fat content of shortbread with sweet potato powder was reduced by 7.5 %, the carbohydrate content was reduced by 11.5 % and the energy value was reduced by 8 % to 407.8 kcal/100 g. Texture parameters were improved, making shortbread with sweet potato powder less hard, the hardness was reduced by 48 %, but at the same time the fracturability indicators were maintained, the fracturability was reduced by only 2 %, compared to the regular shortbread, which made it more acceptable to consumers. The obtained changes in the nutritional value of the shortbread, the improvement of the texture, the reduction of the gluten content and the presence of a high amount of biologically active substances confirm the effectiveness of using Portu Orange sweet potato powder for dietary low-gluten nutrition.

Keywords: *vegetables, sweet potato powder, microwave vacuum drying, confectionery, food coloring, quality characteristics, dietary food.*

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1. Introduction

Plant-based diets have become increasingly popular recently, but plant-based foods need to be refined to reduce allergens (such as gluten) and provide consumers with complete protein. Consumer concerns about their food choices and their potential health and environmental consequences have led to marked changes in dietary patterns and a growing shift to plant-based foods. Plant-based diets are mainly used to promote a healthy lifestyle, preserve animal life, and improve environmental sustainability [1–4]. Growing public awareness of the quality of food products prompts the food industry to create new recipes and label food according to its consumer preferences (organic, gluten-free, vegan, high-protein food, etc.) over competitors [5]. Europe has the largest market share of gluten-free products [6].

Sweet potato (*Ipomoea batatas*) is a perennial herbaceous plant of the birch family. Sweet potato as a tuberous root crop takes the 7th place in the world crop statistics [7]. Sweet potato (*Ipomoea batatas*) has gained wide popularity as a healthy food product in recent years. Sweet potato is recognized as the sixth most important crop in the world [8]. As the main food crop, sweet potato has become an important part of the diet of the global population [9]. Due to the peculiarities of the climate of Central Europe, which has changed due to the influence of global warming, sweet potatoes of certain varieties can be used on personal energy-independent farms in Ukraine [10]. Sweet potatoes are used as food and non-food raw materials in developed countries [11]. Sweet potatoes are rich in starch, dietary fibers, minerals, vitamins and substances with antioxidant activity [12, 13]. The low protein content of sweet potato can be a problem for its use in the technology of balanced dietary nutrition, but this can be solved by using plant protein isolates with high emulsifying properties [14]. Despite the fact that it is a rich source of carbohydrates, it has a low glycemic index (<55), which indicates its possible use in diets, according to the recommendations of FAO-WHO [15]. Significant variations in the composition of nutrients and various indicators of functional properties were found among sweet potato varieties [16, 17]. Sweet potatoes with different flesh colors have different indicators of chemical composition, biological value, and different amounts of biologically active substances in their composition [18]. Orange-fleshed sweet potato is one of the unique sweet potato varieties due to its significant health benefits in bakery technology [19].

Common methods of baking pastry and bakery products include charcoal and oven baking. However, these methods have many disadvantages, including long processing times, overheating of the food surface, and loss of nutrients [20, 21]. If earlier food products were enriched with various fillers based on grain crops (bran, germs and sprouts), then with the discovery of gluten in wheat and other grain crops, natural fillers began to be made from dry vegetables and protein isolates based on vegetable raw materials [22, 23]. The possibility of replacing gluten-containing raw materials with other ingredients, as well as texturing additives, is confirmed in the technology of confectionery products [24]. Confectionery production is associated with the use of various innovative food additives containing complete vegetable protein to meet the needs of the population's dietary (vegan and gluten-free) nutrition [25]. The production of gluten-free confectionery products with appropriate elasticity and cohesion remains a difficult task. Gluten-free products usually have low nutritional value and lower sensory and nutritional properties [26]. To increase the organoleptic properties and nutritional value of low-gluten food products, it is advisable to use food additives rich in complete protein, such as protein isolate [27]. Gluten-free confectionery products were supplemented with a wide range of additives, such as hydrocolloids, acidifiers, emulsifiers, leavening agents, etc. [28]. Regular flour, which naturally contains gluten, can be deglutinated using bioprocess technologies [29]. However, these compositions of gluten-free products lack dietary fibers and bioactive compounds, which are reasonably necessary for the normal functioning of the body. Sources of dietary fiber and ash in confectionery products include seeds, peels, pits, stems, and cores of fruits and vegetables, which can add biological value to the product [26].

The aim of the research is to determine the effectiveness of using *Portu Orange* sweet potato powder, obtained by the microwave vacuum drying method, in the shortbread recipe, and to create a new low-gluten confectionery recipe with reduced gluten content and replacement of potential allergens. This will allow you to use shortbread for diet food. To do this, it is necessary to investigate the chemical analysis of *Portu Orange* sweet potato, sweet potato powder and the quality characteristics of shortbread, enriched with *Portu Orange* sweet potato powder.

2. Materials and Methods

2.1. Materials and raw materials for research. Sweet potato (*Ipomoea batatas var. Portu Orange*) of the 2022 harvest was purchased from a farm in Kryvyi Rih, Ukraine. Other components of the shortbread recipe were purchased at a local market in the city of Sumy, Ukraine. All reagents, used in the experiment, were of analytical quality.

2.2. Technology of making shortbread. *Dough preparation.* Butter was put in a dough bowl, granulated sugar, melange, salt were added and kneaded for 30 min until a homogeneous mass is obtained. Then they poured flour and continued to knead the dough for 2 min. At the same time, the shortbread must have a smooth surface without lumps and traces of poor kneading.

Formation. The dough was cut into 2 kg pieces and rolled out on the table into layers. Then the layers were cut and transferred to sheets with a rolling pin. Excess dough was cut off at the edges of the sheet. Before baking, the surface of the dough was pierced in several places, so that it would not swell. Sheets for baking shortcrust dough were not greased. The dough for the rings was rolled out to a thickness of 6–10 mm.

Baking. The duration of baking the rings at a temperature of 200–225 °C is 10–15 min.

2.3. Determination of physical and chemical composition. The chemical composition of *Portu Orange* sweet potato samples, sweet potato powder and shortcrust dough with their addition was analyzed, including measurements of moisture, starch, sugar and ash [30]. The fat content was analyzed by the Soxhlet extraction method, the protein content by the Kjeldahl method, and the total dietary fiber content – by the enzymatic-gravimetric method [30]. The energy value of shortbread in kcal per 100 g was determined by the calculation method.

2.4. Microwave vacuum drying of beets. Fresh beets were washed, cleaned and cut into slices with a diameter of 5 mm and a thickness of 2 mm. Beetroot slices were first placed evenly on a tray, and then placed in a microwave vacuum dryer. The drying process was carried out at a microwave power of 750 W and a vacuum degree of 0.09 MPa. After drying for 60 min, the microwave power was switched to 450 W to continue drying. The drying process was stopped when the final moisture content of the beet slices was less than 6.5 %. The beet slices were crushed, passed through a sieve, the beet powder was packed in a plastic bag and stored at 25 °C for further use.

2.5. Structural analysis of shortbread. *Analysis of texture characteristics:* A texture analyzer, equipped with a cylindrical probe (P2), was used to determine the hardness and fracturability of the shortcrust dough.

The parameters were as follows: test force using the puncture mode; preliminary speed and test speed of 1 mm/s; post speed 5 mm/s and test distance 10 mm; descent force 5.0 g. Six measurements were made for each sample, and the average value was calculated.

2.6. Organoleptic indicators. Ten experts evaluated shortbread using the Score Card method to assess sensory parameters, namely: color, consistency, aroma, taste, and overall acceptability [31]. The obtained values from the participants were evaluated using one-way analysis of variance and expressed as the mean value.

2.7. Statistical analysis. The results of the studies were expressed in the form of an average value with the number of experiments $n=6$ and standard error $\alpha<0.05$.

3. Results and Discussion

The chemical composition of the *Portu Orange* sweet potato, grown in Ukraine, was studied in order to determine its possibilities in shortbread technology. The general chemical composition of sweet potato is given in Table 1.

Table 1

Chemical composition of *Portu Orange* sweet potato

Nutritional value, g/100 g	Sweet potato *Ipomoea batatas var. Portu Orange*
Moisture	75.5
Starch	11.2
Natural sugars	4.7
Dietary fibers	3.8
Protein	3.6
Fat	0.1
Ash	1.1

The results of the chemical composition study showed that *Portu Orange* sweet potato has a high nutritional and biological value. This may be due to the fact that the sweet potato was grown on chernozems in the conditions of a small farm, which increased its nutritional value. *Portu Orange* sweet potato is particularly rich in dietary fiber (3.8 %), protein (3.6 %) and ash (1.1 %), which are crucial in the diet and daily nutrition of the population.

Sweet potato is used in powder form in confectionery technology. Sweet potato powder is made by microwave vacuum drying, which is one of the innovative methods of drying vegetables. Sweet potato powder is well stored (up to 2 years) under standard storage conditions and has many ways of application in food enterprises.

The chemical composition of *Portu Orange* sweet potato powder will allow you to calculate the optimal recipe for confectionery products. The general chemical composition of *Portu Orange* sweet potato powder is given in Table 2.

Table 2

Chemical composition of *Portu Orange* sweet potato powder

Nutritional value, g/100 g	Sweet potato *Ipomoea batatas var. Portu Orange*
Moisture	6
Starch	43
Natural sugars	18
Dietary fibers	14.6
Proteins	13.8
Fat	0.4
Ash	4.2

Portu Orange sweet potato powder has high indicators of biological value and is suitable for replacing sugar, chicken eggs and part of wheat flour in the recipe. Sweet potato powder is well suited for the industrial production of confectionery products and allows you to store sweet potatoes for a long time and increase its export potential. Although *Portu Orange* sweet potato can be grown in Ukraine, one should not forget about the export of powder from its main producers, such as China, Malawi, Tanzania, Angola and Ethiopia. Reducing the mass of sweet potatoes due to moisture evaporation by 4 times will significantly reduce the costs of its transportation and storage.

The effectiveness of adding *Portu Orange* sweet potato powder to the cookie recipe was investigated. Standard shortbread recipes contain allergens, such as wheat flour and egg products. However, sweet potato powder does not have the properties necessary to completely replace gluten in wheat flour, but the starch content allows for a partial replacement. Therefore, the wheat flour in the cookie recipe was replaced with *Portu Orange* sweet potato powder by 20 % (mass/mass), as this amount is optimal, given the amount of starch in the sweet potato, and it is standard for replacing wheat flour with root vegetable powder in confectionery recipes. Another share of wheat flour (80 %) is replaced by low-gluten wheat flour, which allows to further reduce the amount of gluten in the recipe. *Portu Orange* powder is suitable for replacing egg products, due to the high amount of starch (43 %), and sugar, due to the presence of natural sugars (18 %), which greatly simplifies and improves the shortbread recipe, given in Table 3.

Table 3

Shortbread recipe enriched with *Portu Orange* sweet potato powder

<table>
<tr><th colspan="2">Raw material name</th><th rowspan="2">Raw material consumption for 1 kg of shortcrust dough</th></tr>
<tr><th>Shortbread</th><th>Shortbread enriched with sweet potato powder</th></tr>
<tr><td rowspan="2">Wheat flour</td><td>Low-gluten wheat flour</td><td>440</td></tr>
<tr><td rowspan="3">Sweet potato powder</td><td>135</td></tr>
<tr><td>Sugar</td><td>180</td></tr>
<tr><td>Chiken eggs</td><td>85</td></tr>
<tr><td colspan="2">Cream butter</td><td>200</td></tr>
<tr><td colspan="2">Salt</td><td>20</td></tr>
<tr><td colspan="2">Totally</td><td>1045</td></tr>
<tr><td colspan="2">Shortbread output, %</td><td>95.7</td></tr>
</table>

The orange shades of *Portu Orange* sweet potato color, as a substitute for chicken eggs, are successfully combined in the shortbread recipe, enriched with *Portu Orange* sweet potato powder. The total amount of *Portu Orange* sweet potato powder in the recipe was 400 g, which significantly affected the organoleptic parameters and chemical composition of the shortbread. The high output of shortbread (95.7 %) is explained by the fact that a significant amount of sweet potato powder when reconstituted in the dough, when water is added, significantly increases its volume due to moisture binding.

In order to analyze the quality characteristics of shortbread, enriched with *Portu Orange* sweet potato, its chemical and textural analysis was carried out. The chemical composition of shortbread is shown in Fig. 1.

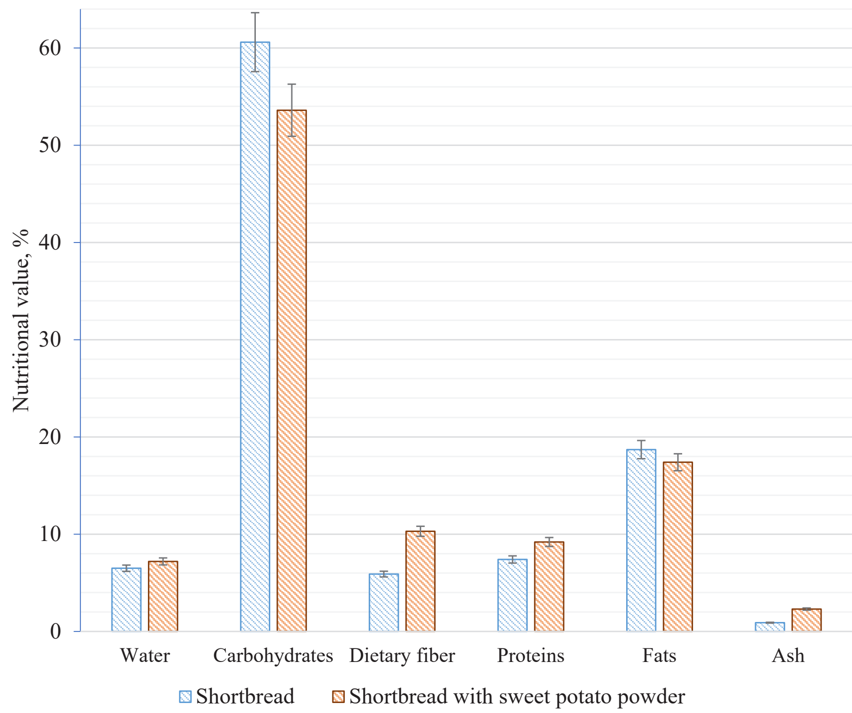

Fig. 1. Chemical composition of shortbread with *Portu Orange* sweet potato powder

Data from Fig. 1 show that after adding *Portu Orange* sweet potato powder to the shortbread recipe, its chemical composition changed significantly. The protein content increased by 24.3 % to 9.2 g/100 g of the product compared to regular shortbread. The slight increase in the protein content is due to the fact that low-gluten wheat flour contains significantly less protein (gluten) in its composition. Dietary fiber content increased by 74.6 % to 10.3 g/100 g of the product and ash by 155.6 % to 2.3 g/100 g compared to regular shortbread. The fat content in shortbread with sweet potato powder decreased by 7.5 %, the carbohydrate content decreased by 11.5 %, which significantly affected the energy value of the shortbread under study and it decreased by 8 % to 407.8 kcal/100 g of the product. The obtained changes in the nutritional value of shortbread confirm the effectiveness of using *Portu Orange* sweet potato powder for dietary nutrition.

A large amount of *Portu Orange* sweet potato powder in the shortbread recipe softened its structure, which is shown in Table 4.

Table 4

Texture analysis of shortbread enriched with *Portu Orange* sweet potato powder

Texture idicator	Shortbread	Shortbread enriched with sweet potato powder
Hardness, g	278	188
Fracturability, g	320	314

After adding sweet potato powder to the shortbread recipe, the consistency of the cookies improved. Its hardness has decreased by 48 %, compared to regular shortbread, due to the presence of a large amount of vegetable raw materials in the recipe. The fracturability of shortbread, enriched with sweet potato powder, was reduced by only 2 % compared to regular shortbread. A significant reduction in hardness, but almost the same fracturability significantly improved the texture of shortbread, enriched with *Portu Orange* sweet potato powder. The obtained texture indicators can be explained by the increase in the moisture content by 10.8 %, protein and dietary fiber in shortbread with sweet potato powder (Fig. 1).

Organoleptic indicators in terms of color, taste, consistency, smell and general acceptability of shortbread are shown in Fig. 2.

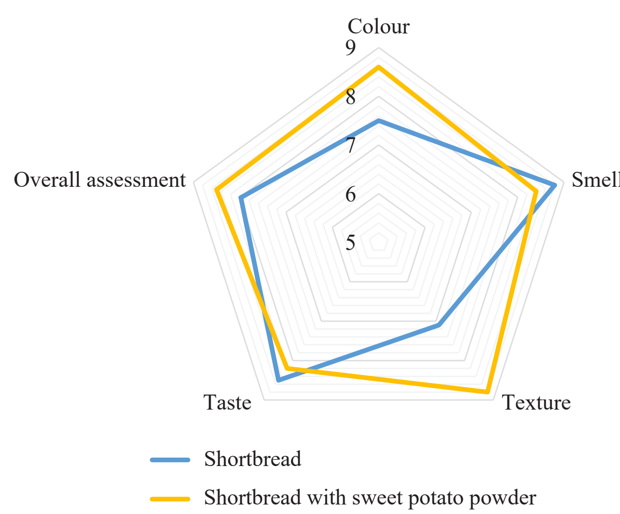

Fig. 2. Organoleptic assessment of shortbread enriched with *Portu Orange* sweet potato powder

The data in Fig. 2 are given as average values, after tasting by ten experts. Shortbread, enriched with *Portu Orange* sweet potato powder, had higher scores for texture, color and overall acceptability compared to regular shortbread. Smell and taste scores were lower than regular shortbread due to the high vegetable content, which did not significantly affect overall acceptability, which was 6.2 % higher for *Portu Orange* sweet potato shortbread.

The shortbread under study was highly rated by experts for its natural orange color, which is related to the rich orange color of the *Portu Orange* sweet potato variety, which was formed by combining β-carotene pigmentation of the skin (orange) and β-carotene pigmentation of the pulp (light orange). The overall acceptability of the sweet potato powder cookies was high, given that they would be used as dietary supplements in low-gluten diets.

Sweet potato powder (*Ipomoea batatas var. Portu Orange*) is a new raw material for the food industry that can replace sugar and egg products, as well as part of gluten in confectionery technology. Sweet potato semi-finished products can also be used in other food recipes, where it is necessary to add food coloring or natural sugar and enrich the food with vegetable protein, dietary fibers and minerals.

The obtained research results were largely influenced by the variety of sweet potato, the results may differ when using a different variety.

The state of war in Ukraine slowed down the research due to the destruction or termination of the work of laboratories and research institutes, and the support of researchers from the European Union, England and the USA was not implemented in practice. This situation led to the search for other places to conduct the research, which made it difficult and reduced the accuracy of the experiments.

Further research should be directed at the addition of *Portu Orange* sweet potato powder to the recipes of other food products and to analyze the color change of food products with sweet potato powder on professional equipment. It is necessary to investigate in more detail the mineral and vitamin composition of sweet potatoes of the *Portu Orange* variety, grown on the chernozems of Ukraine.

4. Conclusions

The obtained research results confirm the effectiveness of using *Portu Orange* sweet potato powder in confectionery technology. Sweet potato powder is suitable for use as a food coloring (orange color) and a source of protein, dietary fiber, starch and minerals in shortbread production. The protein content increased by 24.3 %, dietary fiber by 74.6 %, and the mineral content by 155.6 % compared to regular shortbread Despite the complete replacement of chicken eggs, sugar and regular wheat flour with sweet potato powder and low-gluten wheat flour in the recipe, shortbread with sweet potato powder *Portu Orange* received high organoleptic indicators and improved texture values, which is related to the quality of sweet potato powder, obtained by the method of microwave vacuum drying. Sweet potato semi-finished products can also be used in other food recipes, where it is necessary to add food coloring or natural sugar and enrich the food with vegetable protein, dietary fibers and minerals. The high content of vitamin A and β-carotene in sweet potato and shortbread with its addition provides antioxidant properties to the food product and, together with the reduction in the content of gluten and other allergens in the recipe, improves the prerequisites for its use in dietary nutrition. Further research should be directed at the addition of *Portu Orange* sweet potato powder to the recipes of other food products and to analyze the color change of food products with sweet potato powder on professional equipment. It is necessary to investigate in more detail the mineral and vitamin composition of sweet potatoes of the *Portu Orange* variety, grown on the chernozems of Ukraine.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results, presented in this paper.

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Data availability

The manuscript has no associated data.

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