Use of pseudo cereals in food production

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Abstract. Pseudo-cereals grains, edible seeds, which belong to dicotyledonous plants, are becoming in demand in the human diet as gluten-free grains with excellent nutritional and nutraceutical value. Quinoa, amaranth and buckwheat are the most important pseudo-cereals. Recently, pseudo-cereals have attracted attention because of their high nutritional value of proteins, and their storage proteins are not toxic to celiac patients. In addition, seeds are an important source of dietary fibre and phenols, which are beneficial to health. Research has shown the suitability of amaranth, quinoa and buckwheat flour as a substitute for grain flour in the production of gluten-free biscuits. The article represents data on the chemical and functional composition of amaranth, quinoa and buckwheat and considers the production possibility of gluten-free biscuits using an experimental mixture design to optimize a ternary mixture of amaranth, quinoa, and buckwheat flour in terms of colour parameters, specific volume and hardness. Nutritional and sensory aspects of the optimized formulation were also assessed. The resulting biscuits based on the flour blend of pseudo-cereals were characterized as a product rich in dietary fibre, a good source of essential amino acids, linolenic acid and minerals, with good sensory acceptability. The data presented testify to the possibility of using the flour blend of amaranth, quinoa and buckwheat as an alternative ingredient for gluten-free biscuits.

1. Introduction
Celiac disease is an autoimmune enteropathy caused by the intake of gluten-containing cereals (wheat, barley, rye, and possibly oats) in genetically susceptible individuals. Celiac disease is one of the most common lifelong diseases worldwide, which has the average prevalence rate of 1 per cent from the total population. The only accepted treatment for celiac disease is to continually maintain a strict, life-long gluten-free diet [1]. Therefore, the demand for gluten-free products is increasing, and for this reason, it is necessary to use new raw materials which can substitute wheat flour in the production of bakery, flour confectionery products and pasta. Gluten-free cereals are often based on refined gluten-free flour or starch, which are, as a rule, not fortified with vitamins and other functional ingredients [2]. As a result, many gluten-free cereals do not contain the same amount of B vitamins, iron, and fibre in contrast to their gluten-containing counterparts. In addition, in percentage terms, the disbalance in total dietary energy intake from carbohydrate in patients with celiac disease on a gluten-free diet may have nutritional implications in connection with dietary intake of B vitamins, iron and fibre, since cereals constitute a high percentage of the daily intake of these nutrients. This shows that, when developing new types of gluten-free products and choosing raw materials, special attention must be paid to the content of functional ingredients [3]. From this point of view, pseudo-cereals such as amaranth, quinoa and buckwheat can be a good alternative to traditional gluten-containing grains.
Though botanically amaranth, quinoa and buckwheat are not true cereal grains. Unlike most grains (e.g. wheat, rice, barley), which are monocotyledonous, they are dicotyledonous plants. They are called pseudo-cereals since their seeds in many ways resemble those of true grains in function and nutrient composition [4]. One of the well-studied pseudo-grains for the formulation of gluten free biscuits is buckwheat. It is characterized by the unique concentration of phytochemicals, in particular, rutin. Buckwheat flour is able to retain its antioxidant capacity after heat treatment. The study of substitution of rice flour by buckwheat flour (proportions of 10, 20 and 30 %) revealed high mineral availability, antioxidant potential, phenolic levels and the increased rutin content in comparison with a control group of biscuits based only on rice flour [5]. Quinoa is highly nutritious, has excellent protein quality (it contains all essential amino acids) and a wide range of minerals and vitamins. Although these cereals are very nutritious, they are used in very few food products because of the lack of gluten [6]. However, in the past few years quinoa and quinoa flours have been found in various foods because of the growing interest in their healthy properties. The authors [7] developed a quinoa-based biscuits using both quinoa flour and flakes mixed with cornstarch. The addition of quinoa flour to wheat biscuits improved all nutritional and sensorial properties. Due to its composition amaranth can be used to improve the diet of celiac disease patients [8]. Its lipid content is about 6-8 %, and the lipid profile is similar to that of cereals. It also exhibits high soluble fibre content compared to cereals. The amino acid composition of amaranth proteins is close to optimal for human consumption. It also contains significant amounts of minerals and vitamins. Amaranth is also rich in antioxidant compounds such as tocotrienols, tocopherols, flavonoids, and other phenolic compounds. Studies of the use of amaranth in biscuit production have shown that sprouted flour can be used to obtain highly acceptable biscuits with good nutritional quality [9].

2. Materials and methods

In order to characterize the chemical composition, the protein content was analyzed following the Kjeldahl Method, the lipid content was determined using the Soxhlet extraction method with petroleum ether; the contents of carbohydrate, dietary fibre and ash were also determined in the studied products. During the research a flour blend recipe was formulated for the production of gluten-free biscuits based on amaranth, quinoa and buckwheat taking into account the desirability function. Texture properties of gluten-free dough were determined on a texture analyser Instron-4301. The biscuits were evaluated for physical characteristics like diameter, thickness and their ratio, the tensile strength of biscuits was determined by a TA-HDi Texture Analyzer, Stable Micro Systems, UK. A sensory quality assessment of biscuits was also carried out.

3. Results and their discussion

The study of chemical composition of quinoa, amaranth and buckwheat has shown that they contain significant amounts of physiologically functional ingredients. Table 1 shows the chemical composition of the studied pseudo-cereals determined on a dry matter basis in comparison with wheat and rice, which are often used for the development of gluten-free confectionery flour products.

| Sample       | protein | fat | carbohydrates | dietary fibres | ash  |
|--------------|---------|-----|---------------|----------------|------|
| Amaranth     | 16.5    | 5.7 | 61.4          | 20.6           | 2.8  |
| Quinoa       | 14.5    | 5.5 | 64.2          | 14.2           | 2.7  |
| Buckwheat    | 12.5    | 2.1 | 58.9          | 29.5           | 2.1  |
| Wheat        | 11.3    | 1.7 | 63.7          | 12.2           | 0.6  |
| Rice         | 6.8     | 0.7 | 79.7          | 0.6            | 0.5  |

The data obtained show that the protein content of amaranth, quinoa and buckwheat is higher than in wheat and rice, and the highest protein content is found in amaranth. It should be noted that the proteins
of amaranth, quinoa and buckwheat are composed mainly of globulins and albumin and contain very little or no prolamine, basic proteins found in the seeds of cereals. Research has shown that pseudo-cereals such as amaranth, quinoa, and buckwheat are good sources of dietary fibre. In particular, the fibre content of buckwheat seeds is significantly higher compared to amaranth and quinoa, which, in their turn, have a slightly higher content of dietary fibre than wheat.

Although the total fibre content of quinoa and amaranth is comparable to that of other grains, the monosaccharide subunit composition of these fibres is similar to that of fruits, vegetables and legumes. Insoluble fibres of quinoa and amaranth consisting mainly of subunits of galacturonic acid, arabinose, galactose, xylose and glucose account for 78% of the total fibre content in them. Meanwhile, the soluble dietary fibres of quinoa and amaranth consisting mainly of glucose, galacturonic acid and arabinose subunits account for 22% of the total dietary fibre. Their soluble fibre content is higher than in wheat or rice (≈15% each), so quinoa and amaranth may also have potential beneficial effects on human health. Quinoa is fructan-free and low in fructose, so it does not cause irritable bowel syndrome. Fibre content of buckwheat is higher than other pseudo-cereals, although with lower ratio of soluble to insoluble fibre. Dietary fibres of buckwheat consist of lignin, hemicellulose and cellulose. Thus, the inclusion of these seeds in the diet of celiac disease patients will help to meet, at least partially, dietary fibre intake needs in this segment of the population.

Traditionally, rice and corn have been main ingredients in gluten-free foods. However, pseudo-cereals can be used as alternative ingredients in gluten-free formulations because of their high nutritional value. They are a valuable source of a wide range of bioactive compounds. As the pericarp of quinoa has a high content of saponin, it is usually removed by mechanical means or washing before the use of seeds. Dehusked quinoa keeps the nutrient-rich embryo and endosperm intact. For processing into gluten-free food buckwheat seeds must be dehulled, while all amaranth seeds are simply ground into flour to be used for gluten-free foods.

Biscuits are a widely consumed type of flour confectionery products due to their long shelf life and high consumer properties. The structure-forming ability of gluten affects the rheological properties of dough and the overall appearance of baked goods. In biscuits the gluten network formation of dough is minimized and undesirable. Thus, it is easier to produce gluten-free biscuits rather than their gluten-rich counterparts. A biscuit composition based on the flour blend of pseudo-cereals of amaranth, quinoa and buckwheat was developed, which amounted to 55.7% of the total weight of all ingredients in the gluten-free biscuit recipe. Altogether, thirteen experimental variants of flour blend formulation were obtained by varying the content of each component of the blend within the range of 1 to 100%. The order of analyses was randomized, while the dependent variables analyzed in each test were colour, hardness and specific volume of biscuits. Measurements of the colour and texture properties of gluten-free biscuits are presented in Table 2. The light reflectance value characterizing changes in the degree of darkening (from 100 - the lightest to 0 - the darkest) L* decreased with the increase of buckwheat ratio within the flour blend. Moreover, biscuits with 100% buckwheat flour had the darkest colour.

When the studied samples of the flour blend were used, the hardness value of gluten-free biscuits was in the range from 51.11 to 70.14 N. The biscuits based only on buckwheat had the highest hardness value, the addition of amaranth and quinoa to the gluten-free flour blend had a positive effect on the hardness index, which decreased with the increase of these components in the composition of the blend. It can be connected with the fact, that buckwheat flour is a good source of dietary fibre which contributes to the increased biscuits hardness. In addition, the increase in the protein content can also lead to the increase in the hardness of finished goods, but to a lesser extent. Amaranth and quinoa contain a large amount of protein and slightly less dietary fibres than buckwheat, which, in turn, affects the fact that biscuits produced from pseudo-cereals have a lower hardness. Quinoa and amaranth had the greatest positive effect on the specific volume of the evaluated biscuits.

Recipes, where the buckwheat flour content was higher compared to quinoa and amaranth, had lower specific volume of gluten-free biscuits indicating a negative interaction between buckwheat and quinoa flour or between buckwheat and amaranth flour. In contrast, the interaction between quinoa and amaranth had a positive effect, when the amount of amaranth was less than the amount of quinoa, as
evidenced by an increase in specific volume. The effect was the opposite for gluten-free biscuits, when the buckwheat flour content was higher than that of quinoa. Dough slackness is primarily a physical process controlled by the ability of ingredients to retain moisture, thus, the increase in the number of ingredients with this property, for example, buckwheat, causes the competition for free moisture in biscuits limiting the rate of dough extension. In addition, there is a correlation between an increase in the protein content and decrease in the rate of dough slackness, which explains why the volume of gluten-free biscuits decreases with an increase in the amount of quinoa and amaranth flour compared to buckwheat.

Table 2. Influence of amaranth (A), quinoa (K) and buckwheat (G) on the colour and texture properties of gluten-free biscuits

| Sample | Content in the flour blend | Indicators | | |
|--------|---------------------------|------------|-------|-------|
|        | amaranth | quinoa | buckwheat | colour | hardness, N | specific volume, cm³/g |
| 1      | 1 | 0 | 0 | 60.88 | 62.48 | 1.57 |
| 2      | 0 | 1 | 0 | 61.64 | 51.11 | 1.63 |
| 3      | 0 | 0 | 1 | 48.98 | 70.14 | 0.80 |
| 4      | 0.33 | 0.67 | 0 | 59.67 | 56.37 | 2.27 |
| 5      | 0.33 | 0 | 0.67 | 50.66 | 68.61 | 0.83 |
| 6      | 0 | 0.33 | 0.67 | 49.10 | 63.80 | 0.85 |
| 7      | 0.67 | 0.33 | 0 | 60.58 | 59.69 | 1.88 |
| 8      | 0.67 | 0 | 0.33 | 69.72 | 66.03 | 0.97 |
| 9      | 0 | 0.67 | 0.33 | 70.61 | 57.45 | 0.98 |
| 10     | 0.33 | 0.34 | 0.33 | 70.48 | 61.24 | 1.17 |
| 11     | 0.66 | 0.17 | 0.17 | 75.65 | 62.86 | 1.05 |
| 12     | 0.17 | 0.66 | 0.17 | 71.23 | 56.18 | 1.23 |
| 13     | 0.17 | 0.17 | 0.66 | 60.98 | 65.69 | 0.92 |

Thirteen experimental flour blends based on pseudo-cereals were investigated considering the desirability profile and as a result of mathematical processing of the experimental data, the optimal composition of a gluten-free flour blend in the ratio of 30 % amaranth, 45 % quinoa and 25 % buckwheat was obtained. The optimized gluten-free flour blend recipe with the mixture of pseudo-cereals showed L* = 71.26, a hardness of 53.17 N, and a specific volume of 1.20 cm³/g. The analysis of the nutritional and energy value of a prototype of gluten-free biscuits produced according to the optimized recipe is shown in Table 3.

Table 3. Nutritional and energy value of the developed gluten-free biscuits

| Content | % |
|---------|---|
| Moisture | 3.33 |
| Protein | 7.38 |
| Fats | 18.69 |
| Carbohydrates | 56.39 |
| Dietary fibre | 12.62 |
| Ash | 1.59 |
| Energy value, kcal | 429.65 |

Optimized gluten-free biscuits are positioned as high-fibre foods due to their high dietary fibre content, which is 12.62 g/100 g in baked biscuits. Taking into account the FAO / WHO recommended fiber intake (25 to 30 g per day) for adults for preventing diet-related chronic diseases, the consumption of four gluten-free biscuits a day can provide approximately 22 % of the recommended daily fiber intake. The water activity values and moisture content for gluten-free biscuits were 0.37 % and 3.33 %, respectively, which indicated good storage stability of the finished product. Low moisture is a positive parameter associated with crunch, an important desirable sensory attribute for biscuits.
The average score of overall perception for the optimized gluten-free biscuits based on the flour blend of three pseudo-cereals is 6.8 which is categorized as “liked” on a nine-point hedonic scale. When asked about the intent to purchase the evaluated product, respondents note that they would “probably buy” it (score 4.0).

4. Conclusions
Thus, the studies carried out prove that the optimized ternary flour blend based on pseudo-cereals such as amaranth, quinoa and buckwheat, followed by the use of the experimental blend in the analysis of such parameters as hardness, colour and specific volume of gluten-free biscuits, is a good source of fibre, amino acids, essential fatty acids and minerals. Biscuits with optimized flour blend formulation based on amaranth, quinoa and buckwheat have shown good sensory acceptability and definite audience purchase intent unlocking the potential of gluten-free biscuits for human consumption in general and being an interesting alternative for people with celiac disease. The data presented testify to the potential of pseudo-cereals to be useful as an alternative ingredient for gluten-free biscuits.

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