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Application possibilities of pseudocereals in product development

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1. Summary

In our research, experiments have been conducted on bakery product development. Our goal was the creation and chemical testing of a product that is rich in antioxidants and has favorable properties from a nutrition physiology point of view. In our experiments, bakery products were produced using different mixing ratios of BL55 wheat flour, amaranth and buckwheat flours.

The consumption of buckwheat and amaranth has not yet gained wide acceptance among Hungarian consumers. Their taste could be strange to consumers, which can cause rejection. Therefore, we tried to make the products' organoleptic properties more favorable to consumers by using different spices. By the addition of the spices, the antioxidant capacity of the finished products could also be increased.

Due to their high polyphenolic components, vitamin and mineral contents, buckwheat and amaranth are known to have beneficial physiological effects. Ground to flour, they can be used in everyday kitchen technology and baking industry practice. At the same time, since they do not contain gluten, the mechanical properties of pastas made from their flours are much weaker than what is characteristic of products made from grains. To improve baking industry properties, in addition to the application of hydrocolloids, large quantities of various food additives are used by the baking industry, such as hydroxypropyl methyl cellulose, guar gum or dextrose. However, counter-reactions may be triggered by these additives in individuals sensitive to them as well as „health-conscious" consumers are also reluctant to accept foods prepared with such additives. For this reason, such ingredients were not used in our product development.

In our experiments, we focused on the development of a snack product, because Hungarian people willingly consume snack foods. Storage experiments were carried out with our products, during which their antioxidant properties were investigated by FRAP method. In addition, water activity, moisture content and rheological properties of the products were also investigated.

Our experimental products not only possessed favorable sensory properties, but exhibited good chemical characteristics as well. As a result of baking, their water-soluble antioxidant capacity increased, and the use of spices had a favorable sensory effect on the characteristic taste of the pseudocereals. Storage experiments confirmed that the products can be consumed for several days. Due to their antimicrobial properties, in addition to improving taste, spices can also increase the shelf-life of the products.

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2. Introduction

Grain-based products and cereal grains, when consumed for breakfast or as part of a snack, provide the body with the ideal daily intake of useful chemicals, various fibers and other compounds. Therefore, consumption of cereals several times a day is recommended **[1] [2]**.

Today, it is increasingly important to supplement our cereals, in addition to the dominant grains, such as wheat, corn and rice, with other grains and pseudocereals **[3]**.

Amaranth and buckwheat have excellent nutritional-physiological effects, therefore, they can be used as valuable raw materials or additives in modern food processing, thereby improving the texture, sensory properties and nutritional value of the food **[4]**.

The main carbohydrate ingredient of amaranth is starch. Unlike other cereals, the starch in amaranth has excellent freezing-melting and retrogradation stabilities, it forms a gel at higher temperatures, has a higher viscosity and a high water-binding capacity. Its water solubility and swelling ability are also outstanding **[5]**. The other carbohydrate components of amaranth, mono- and disaccharides are present in the plant in small amounts. Their approximate quantities: sucrose: 0.6 g/100 g, galactose: 0.38 g/100 g, glucose and fructose altogether: 0.14 g/100 g. Fiber content varies between 19 and 50% by variety **[6]**.

The carbohydrate content of amaranth is favorable from a nutritional-physiology point of view. However, its significance lies in its protein content **[7]**. Early experiments aimed at the comparison of amaranth and soy proteins have shown that amaranth proteins have better solubility, as well as better foaming and emulsifying properties [8]. Its high protein solubility also makes it suitable for the production of functional foods **[9]**. Among essential amino acids found in different amaranth varieties, lysine content is high in the seeds, which plays a role in muscle building and regeneration. The flour made from amaranth seeds contains two to three times more lysine, arginine, tryptophan and sulfur-containing amino acids than wheat flour **[10]**.

The main component of buckwheat is starch, which accounts for more than 70% of the seed's dry matter content **[11]**. The amylose/amylopectin ratio of buckwheat starch is 1:1. In this respect, buckwheat starch is different from grain starch, and is more similar to high amylose content corn starch. Buckwheat starch forms a gel at a higher temperature, its viscosity is higher than that of grain starch, which can be explained by the presence of glucan **[12]**.

33 to 37% of buckwheat starch is resistant starch **[13]**, therefore, it is very useful for the development of foods with low glycemic indices. However, as a result of heat treatment processes (e.g., cooking or drying at 110 °C), its quantity is reduced to ~7% **[14]**.

Compared to traditional flour, buckwheat's fiber content is significant, 25.7 grams per 100 g product, while in wheat flour it is only 11.71 g. Since the carbohydrate components of buckwheat are absorbed slowly (its glycemic index is ~50-59), when consuming foods made with buckwheat, blood glucose levels rise slower and to a lesser extent than in case of products made from wheat flour.

The protein content of buckwheat depends on the plant variety and the environment, it is generally within a 7 to 21% range. Seeds of the most commonly cultivated varieties contain 11 to 15% protein.

Buckwheat has beneficial nutritional-physiological effects. Buckwheat proteins reduce the risk of developing kidney stones and they lower cholesterol levels more effectively than soy proteins **[15]**. These proteins also reduce the risk of developing colon cancer, because they inhibit the unlimited growth of intestinal wall cells **[16]**. The dietary fiber content of buckwheat also contributes to its beneficial effects. Since buckwheat does not contain gluten-forming protein, it is not possible to make loose-structured bakery products from its flour **[17]**.

The distinctive taste of buckwheat and amaranth may be a source of aversion in consumers. Their flavor can be improved by the addition of spices. Some spices have digestion stimulating, anti-bloating, anti-inflammatory and cancer-preventing effects. Research of the active components of spices and herbs as intact products is also ongoing **[18]**. Spices that may be added to buckwheat and amaranth flour could be sources of numerous polyphenolic compounds **[19]**. Spices have double function, besides their high antioxidant capacity they also possess antimicrobial effects, which may increase the shelf-life of the products **[21]**.

During the preparation of a product it is subject to different changes that take place in the course of the cooking processes. These processes can potentially alter the antioxidant content of the product available to consumers **[20]**. Chohan et al. have shown that the antioxidant capacity of plant-based foods may change in either positive or negative direction during various kitchen technology processes, but it may also remain unchanged **[22]**.

The chemical behavior of antioxidants after cooking is related to their molecular structure. For example, active polyphenolic flavonoids are more heat-resistant than vitamins and related compounds. Furthermore, additional antioxidants or phenolic compounds may form during baking, which can increase the antioxidant potential relative to the level of the starting materials **[20]**.

In our experiments, we endeavored to develop a buckwheat or amaranth flour enriched wheat flour based snack product with adequate sensory properties. To achieve this, the correct flour mix ratio and baking method were determined, and it was investigated how the antioxidant capacity of the raw materials and the finished products change with the various mixing ratios and making methods. To improve sensory characteristics, various spices and spice combinations were used, and then it was examined whether the presence of the spice had resulted in a change in any of the parameters during the preparation. Rheological processes, as well as changes in moisture content and water activity in the finished product during storage were also monitored.

3. Materials and methods

In the course of our work, commercially available ground caraway seeds (*SPAR*), ground rosemary (*Le Gusto*), ground white pepper (*Kotányi*), basil and marjoram (*Horváth Rozi*), spice blend (*Vegeta Naturella spice blend*), 2.8% fat milk (*Magyar Tej*), butter (*Magyar vaj*), table salt, BL55 wheat flour (*Gyermelyi BL55*), as well as commercially available buckwheat flour (*Glutenex*) and amaranth flour (*Szarlat*) were used.

In our experiments, the antioxidant capacity of the spices and flour mixtures were investigated and, based on the results, the recipe was developed. The antioxidant capacity of the dough thus obtained and of the finished products made from them were tested. For the baking of the products, a Hauser ST-637 waffle iron was used at setting 5. Baking time was determined to be six minutes.

For the measurement of antioxidant capacity, samples were homogenized, 0.10 g/ml distilled water was added and they were centrifuged for 15 minutes (Hermle Z 100M) at 10,000 rpm.

For the tests, extracts were made from BL55 wheat flour, amaranth flour, buckwheat flour, flour mixtures, ground rosemary, ground caraway seeds, ground white pepper, ground basil, ground marjoram, the spice blend and the finished product qualified organoleptically as adequate.

Antioxidant capacity was determined using the FRAP (Ferric Reducing Ability of Plasma) method **[23].** Measurements were carried out at 593 nm, using a Rayleigh UV-1800 spectrophotometer.

For the finished product storage experiments, a commercially available metal box was used. Samples were stored for 72 hours at room temperature. During this time, the moisture content (Sartorius MA 100), water activity (Novasina ms1-aw) and rheological properties of the products were measured. For the investigation of the rheological properties, a distortion penetration method was used, 0, 24, 48 and 72 hours after the preparation of the finished product (TA.XT2i Texture Analyzer). A needle probe with a diameter of 1 mm was used for the measurements. The probe penetration rate was 0.5 mm/s, and the needle traveled 4 mm.

Sensory tests were carried out on the finished products by the students of Szent István University. Descriptive 20-point weighting factor tests based on Section 1.3.1.2 of standard MSZ 20501-2:1989 were carried out to our series of experiments.

Our work was carried out in the Hankóczy Baking laboratory of the Department of Grain and Industrial Plant Processing of Szent István University.

The blending ratios of the flours used are shown in **Table 1**.

During baking, the ingredients were kneaded, and the dough was rolled once with a kitchen pasta machine (Tescoma DELICIA) at setting 1. As a control sample, BL 55 wheat flour, free of pseudocereals was used. Final formulations are shown in **Table 2**.

Since the formulations do not contain additives that increase shelf-life, it is assumed that the samples would not retain their original condition for more than three days. To confirm this assumption, changes in the moisture content, water activity and hardness of the samples were followed.

Statistical evaluation of the test results (two-sample t-test, single factor variance analysis, two-factor repeat variance analysis) was carried out with the help of the SPSS 15.0 for Windows program (SPSS Inc., Chicago, USA). The selected significance level was min $p \leq 0.005$.

4. Results and evaluation

4.1 Antioxidant capacity of spice extracts

Antioxidant capacities of the ground spices selected for the manufacture of the snack products are shown in **Figure 1**.

The figure clearly shows that rosemary exhibited a remarkably high value of 615.32 mg AA/100 g dry matter compared to the other spices. However, in terms of flavor, it had a negative effect on the finished product. Therefore, rosemary was not included in the formulations.

In case of the spices caraway seeds, basil and marjoram it can be stated that antioxidant capacities did not differ from each other significantly ($p > 0{,}05$), but caraway seeds had a positive effect on the taste of the finished product, so this spice was included in the formulations. The spice blend exhibited a lower antioxidant capacity than the caraway seeds, however, it had a beneficial effect on the taste of the finished product. Therefore, the blend was included in the formulations.

The antioxidant capacity of white pepper was quite low, 17.31 mg AA/100 g dry matter, therefore, when mixed with the flour, it may have a beneficial effect on the organoleptic properties of the product, rather than increase the nutritional value, so this spice was not included in the formulations either.

4.2 Antioxidant capacity of flours and their mixtures

Figure 2 illustrates the antioxidant capacity of wheat flour mixed with buckwheat and amaranth flour in different ratios.

Based on **Figure 2**, it can be concluded that even a 30% buckwheat flour fraction increases the original antioxidant capacity of wheat flour significantly from a value of 1.5 mg AA/100 g dry matter to 7.50 mg AA/100 g dry matter. At a 50% fraction it already approaches the original antioxidant capacity of buckwheat flour of 17.51 mg AA/100 g dry matter. In case of the application of amaranth flour it is clear that the increase in valuable component content of the mixtures is directly proportional to the amaranth content of the mixtures. The antioxidant capacity increased to 20.37 mg AA/100 g dry matter at a 30% fraction, and to 27.38 mg AA/100 g dry matter at a fraction of 50%. In the final formulation, the 50-50% mixing ratio with a more favorable antioxidant capacity was used for both pseudocereal flours.

4.3 Baking results

The effect of baking on the antioxidant capacity is shown in **Figure 3**.

Based on the results it can be stated that the antioxidant capacity of the products shows an increasing trend due to baking. The supposed reason for this is that the bonds between the individual compounds and the various ligands are destroyed, thereby increasing their bioavailability **[24]**. In our case, antioxidant components present in the products are bound to proteins in their original state, and the compounds are released due to baking through the denaturing of proteins **[25]**.

It is conceivable that water-insoluble components with antioxidant effects turn into water-soluble compounds due to heat, thereby increasing the antioxidant capacity of water-soluble components in products that have undergone baking.

This type of increase was not experienced in the case of samples without spices and the control products. It is possible that in these cases the presence of spice also affects the antioxidant capacity of the product. The highest value, 15.19 mg AA/100 g dry matter, was obtained in the case of the product enriched with buckwheat flour and ground caraway seeds, while the lowest value, 7.03 mg AA/100 g dry matter was produced by the product enriched with amaranth flour and the spice blend.

4.4 Sensory tests

Results of the sensory evaluation are summarized in **Table 3**. The weighted total scores of the products did not differ from each other significantly. Overall, based on the high scores (>15), it can be said that each product was considered to be adequate by the judges. Overall results of the products made from the flour mixture enriched with buckwheat are more favorable than that of the control. Products made from the flour mixture enriched with amaranth flour obtained lower scores, but the difference was insignificant from a statistical point of view.

4.5 Moisture content and water activity

Changes in the moisture content and water activity of the finished products during storage are illustrated in **Figures 4 and 5**. It is noticeable that the two properties are related to each other, since the moisture content and the water activity changed similarly.

Overall, it can be stated that on the first day there is a clear difference between the moisture contents of the products. However, with each passing day, the difference decreased more and more, and water activity values levelled off.

The space available to them in the storage container was filled almost completely by the products, therefore, some kind of equilibration process took place between the products with different moisture contents.

At the initial stage of the measurement, the control product had the highest moisture content (10.11%). The lowest value was measured in the case of the product made from the flour mixture enriched with amaranth flour and the spice blend (2.04%). However, the observed difference gradually began to decrease by the end of the storage time. Although the moisture content of the products made from the flour mixture enriched with amaranth flour increased towards the end of storage, however, these products still had the lowest values at all times (3,36% and 3.5%).

From a microbiological point of view, the products can be considered safe, since microorganisms cannot exhibit life activities under a water activity value of 0.6 **[26]** and, with the exception of the control product (0.88), the water activity of each product enriched with pseudocereals remained below this value, even at the initial stage of sampling.

4.6 Rheological studies

During the measurements, the relationship between the storage time and the loadability of finished products (resistance to force of loading weight) was also investigated. For the evaluation, the load-bearing capacities of the products were analyzed by measuring two factors during storage. Loading force was determined at a depth of 1.5 mm (***Figure 6***), because the upper layer of the products in this range is still homogeneous. In addition, the maximum loading force, resulting in the distortion of the finished products, was also determined (**Figure 7**).

In the case of the loading force measured at a depth of 1.5 mm, the products made from the flour mixture enriched with amaranth flour proved to be harder than the products made from the flour mixture enriched with buckwheat flour and the control product ($p<0.05$). The former shape was deformed at a loading force of 1,986 g (19.5 N), while the latter ones at a force of 1,529 g (15.0 N) and 1,089 g (10.7 N), respectively. This was also demonstrated by the fact experienced after baking that products made from flour mixtures enriched with pseudocereal flours were more crispy than the control product. This trend could be observed until the end of the storage experiment. In the case of the products made from the flour mixture enriched with amaranth flour, the loading force necessary for the distortion of the product was 1,801 g (17.7 N) and 1,318 g (12.9 N), while in the case of the control product and the product made from the flour mixture enriched with buckwheat flour the values were 1,088 g (10.7 N) and 1279 g (12.5 N), respectively.

It was found that the presence of spices in the fresh products did not affect the hardness of the samples ($p>0.05$).

Similar results can be observed in the case of the maximum loading force for the finished products. The distortion of the products made from the flour mixture enriched with amaranth flour required greater force (3,925 g – 38.5 N) than the distortion of the control product (1,693 g – 16.6 N) or the products made from the flour mixture enriched with buckwheat flour (3,131 g – 30.7 N) ($p<0.05$). During the storage experiment, no uniform tendency could be detected regarding either the hardening or the softening of the products. In terms of the rheological characteristics, differences may be the consequence in changes in the moisture content during storage.

5. Conclusion

During our work, we focused on the development of bakery products. Our goal was to create bakery products rich in antioxidants and using pseudocereals. A storage experiment was also designed for the developed products, during which we intended to measure their nutritional values. Due to their high polyphenolic components, vitamin and mineral contents, buckwheat and amaranth are known to have beneficial physiological effects. Ground to flour, they can be used in everyday kitchen technology and baking industry practice. However, these flour do not contain gluten and so, when added to wheat flour, they significantly impair its dough-forming properties. To improve these properties, in addition to the application of hydrocolloids, large quantities of various food additives are generally used by the baking industry (e.g., hydroxypropyl methyl cellulose, guar gum, dextrose, etc.), however, counter-reactions may be triggered by these additives in the metabolism of individuals sensitive to them. In addition, the group of „health-conscious" consumers are also reluctant to accept foods prepared with such additives. For this reason, we strove to omit the above-mentioned additives from the list of ingredients of the products designed by us.

Baking (heat treatment) had a beneficial effect on the antioxidant capacity of the water-soluble compounds found in the ingredients of the flour mixtures put together by us. To suppress the unpleasant taste of the pseudocereal components and to improve the organoleptic properties of the products, spices were used. It was confirmed by storage experiments that the products developed by us maintained their high quality for 72 hours and remained consumable. Our experiments were only introductory in nature, further measurements and storage experiments are in progress.

Literature data known to us suggest that Hungarian consumers, regardless of their age, prefer snack-type products. That is why we consider it important, in addition to the usual products in the snack range, to publish and promote the results of the latest product developments.

6. References

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