Prospects of using amaranth as a functional ingredient in bakery products

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Abstract. The paper describes the development of bakery products enriched with amaranth, dry demineralized whey and fine powders obtained from eggshells and vegetables (beets and carrots). The possibility of partial (in amount of 15%) wheat flour replacement with amaranth seeds or amaranth flour is studied. Before grinding into flour, the amaranth seeds were soaked until their shell was softened. After that, the seeds were mechanically ground. It was noted that the accelerated mechanical treatment of amaranth seeds intensified dough preparation process and reduced its duration. The obtained bakery products were evaluated on sensory and physico-chemical characteristics. It was found that the developed bakery products satisfy 14...15% from daily requirements in proteins, β-carotene and calcium, and can be recommended as food products of functional purpose in child, dietary and gerontological nutrition.

1. Introduction
A promising direction in the development of functional bakery products range is the use of natural food fortifiers in their formulations. These types of fortifiers include amaranth seeds, amaranth flour, and such complex additives as fine powders of plant and animal origin.

The research purpose was studying the prospects of using amaranth seeds and amaranth flour for in formulations of functional bakery products.

The research studies according to the purpose were:

- to justify the choice of functional ingredients;
- to develop the formulations of bakery products enriched with amaranth and other functional ingredients;
- to investigate the effect of the introduced ingredients on sensory and physico-chemical characteristics of obtained bakery products;
- to substantiate the functional properties of bakery products.

2. Materials and methods
Based on research purpose and studies, there were developed and obtained the samples of bakery products enriched with amaranth. Among with amaranth, the main ingredients were high-grade wheat
flour, potable water, pressed yeast and dry demineralized whey. The additional ingredients were fine powders from eggshells and vegetables. Vegetable powders were obtained from beets and carrots dried by infrared radiation and finely ground.

2.1. Amaranth
The protein content in amaranth seeds is not less than 16%, the total protein consists of 28...35% of essential amino acids [1–6]. Amaranth proteins are highly digestible, water-soluble and emulsifying. Therefore, it is important to use amaranth in the development of high-protein bakery products formulations. Among amino acids, amaranth is rich with lysine [5, 6], which promotes protein and calcium digestion. This effect improves the relevance of the use of functional ingredients with high protein and calcium content in bakery products formulations.

Amaranth seeds are a source of squalene, important vitamins (A, C, D, E) and minerals (potassium, calcium, magnesium, phosphorus, iron) [2]. Thus, amaranth seeds are a perspective source of functional ingredients in bakery production.

Amaranth flour contains antidepressant ingredients. These ingredients activate the action of serotonin, which has a beneficial effect on the human nervous system. The increased flour acidity causes the rapid accumulation of acids during fermentation. High water-holding capacity of the flour is achieved due to its high dietary fibers content. The gas-holding capacity is determined by rheological properties of the dough obtained from wheat and amaranth flour mix, and thus determines the size and structure of crumb porosity. Therefore, replacing 15% of wheat flour with amaranth flour allows to obtain new bakery product with functional properties. The complete use of amaranth flour instead of wheat flour in bakery product formulations is not possible since it does not contain gluten [7].

The light-colored seeds used in the research have the highest biological potential in comparison with dark-colored seeds.

Before the flour obtaining, the seeds were soaked for shell softening. After that, they were exposed to mechanical treatment.

The amount of amaranth seeds or flour introduced into bakery products formulations with partial wheat flour replacement was 15% of total wheat flour content.

The chemical compositions of amaranth seeds and amaranth flour were determined according to test methods described in Russian national standards GOST 9404-88, GOST 10846-91, GOST 10847-2019, GOST 27494-2016 and GOST 29033-91.

2.2. Dry demineralized whey
Dry demineralized whey is a by-product in cheesemaking. It contains proteins with high biological value and digestibility. Lactose contained in the whey allows to prolongate the shelf-life of bakery products while preventing their staleness, allows better dough loosening, promotes calcium digestion and plays significant role in formation of a golden color in finished bakery products. Besides, the whey contains dispersed milk fat, nicotinic acid, biotin, choline, vitamins and organic acids [8].

2.3. Eggshell powder
Eggshell is one of natural systems, where calcium is kept in a biologically active state. The eggshell contains on 97% from calcium carbonate, which is digested almost completely.

The eggshell also contains other important mineral elements, such as magnesium, phosphorus, silicon, sodium, potassium, iron and aluminum.

Considering the beneficial properties of eggshell, it was introduced into bakery products formulations with amaranth in the form of fine powder. According to obtained results from previously carried-out research, it was estimated that calcium and protein content in finely-ground eggshell is 54.43% and 20.59% accordingly [8].
2.4. Beet and carrot powders of infrared drying
For improving of calcium digestion, antioxidant activity, vitamins and minerals content, in formulations there were introduced fine powders of infrared (IR) drying obtained from beets and carrots.

It is well-known, that beets contain vitamins of B-group, C, organic acids, betaine, mineral substances and bioflavonoids. Pectin compounds of beets take part in the formation of animal sugar - glycogen, which is an important reserve substance for energy processes in animal and human organisms.

The useful properties of carrots are explained by their chemical composition. The main ingredient in carrots is β-carotene. Carrots also contain pectines and mineral substances (potassium, phosphorus, iron and copper) and vitamins B1, B3, B6, C and K [9].

During our previously carried out research, it was estimated that fine powders of IR-drying from beets and carrots have got high nutritional value and antioxidant activity, and also can be used for functional food products obtaining [8].

2.5. Bakery products samples preparing and their evaluation on sensory and physico-chemical characteristics
There were developed and prepared the following samples of enriched bakery production:

- sample № 1 – “Milky” roll (control sample according to “The Digest of Formulations on Production for Students in All Educational Institutions”, 2005);
- sample № 2 – roll with amaranth seeds, dry demineralized whey, eggshell and beet powders;
- sample № 3 – roll with amaranth flour, dry demineralized whey, eggshell and carrot powders.

The optimality of developed formulations was confirmed by mathematical modelling (linear programming). Further, the experimental bakery products samples were obtained according these formulations.

The technology of experimental bakery products samples obtaining consisted of the following stages:

- stage 1: sifted dry whey was diluted with water in ratio of 1:10;
- stage 2: the following ingredients were introduced into obtained mixture in sequence: prepared and activated yeast, amaranth seeds/flour (depending on formulation), beet/carrot powder of IR-drying (depending on formulation), eggshell powder and softened butter. Finally, the sifted flour was introduced into the mixture, and the dough was kneaded.
- stage 3: the kneaded dough was left for fermentation at 38...40 °C within 35 min. Then the fermented dough was cut into rolls weighing 50 g, which were left for proofing at 38...40 °C within 20 min. After that, the rolls were baked at 180...200 °C within 20 min.

Enhanced mechanical processing of the dough causes deeper changes in protein substances, which accelerate its ripening during fermentation, proofing and baking processes.

The obtained bakery products were evaluated on sensory and physico-chemical characteristics according to standard methods described in Russian national standards GOST 5667-65, GOST 5669-96, GOST 5670-96, GOST 13496.17-2019, GOST 21094-75 and GOST 31675-2012.

3. Results and discussion

3.1. Chemical composition of amaranth seeds and amaranth flour
Results of chemical composition of amaranth seeds and amaranth flour are presented in figure 1.

It has been found that both amaranth seeds and amaranth flour have high nutritional and biological value, which is expressed on increased content of proteins, cellulose, vitamins, minerals. Thus, they can be used as ingredients in formulations of new functional food products.
3.2. Evaluation of bakery products samples enriched with amaranth

During preparation of the samples, it has been found that the fermentation process of enriched dough reduced from 75 min to 35 min. The proofing process reduced from 55 min to 20 min, and the baking process reduced from 22–25 min to 20 min. Thus, it can be concluded that the accelerated dough mechanical treatment has a positive effect on preparing process intensification.

The results of sensory evaluation of bakery products samples are shown in figure 2.
Sensory evaluation of samples showed that they can be characterized by porous consistency, nice appearance and good taste, color and scent.

The results of physico-chemical characteristics evaluation of bakery products samples are shown in Table 1.

| Table 1. Physico-chemical characteristics of bakery products samples. |
|---------------------------------------------------------------|
| Characteristics | Bakery products samples | Sample № 1 (control) | Sample № 2 | Sample № 3 |
| Humidity, % | | 36.0 ± 1.3 | 40.3 ± 1.1 | 36.4 ± 1.4 |
| Proteins content, % | | 6.1 ± 0.02 | 13.2 ± 0.02 | 12.1 ± 0.02 |
| Cellulose content, % | | 2.1 ± 0.2 | 3.1 ± 0.01 | 3.1 ± 0.01 |
| β-carotene content, mg/100 g | | – | – | 0.75 ± 0.07 |
| Calcium content, mg/100 g | | – | 495.0 ± 0.05 | 480.0 ± 0.02 |
| Ash content, % | | 1.5 ± 0.002 | 3.04 ± 0.003 | 2.6 ± 0.002 |
| Acidity, °N | | 2.9 ± 0.02 | 4 ± 0.02 | 4.1 ± 0.02 |
| Porosity, % | | 73 ± 0.02 | 78.0 ± 0.2 | 77.5 ± 0.2 |
| Energy value, kcal | | 140.0 ± 0.2 | 119.0 ± 0.4 | 118.0 ± 0.8 |

According to the results of physico-chemical products samples evaluation, the following conclusions can be made:

- considering the requirements of β-carotene and functionality percentage, sample № 3 fills 15% (0.75 g) from their daily need;
- considering the requirements of calcium and functionality percentage, samples № 2 and № 3 fill 15% from their daily need;
- considering the requirements of proteins and functionality percentage, all samples fill 14% from their daily need;
- porosity values of samples № 2 and № 3 are 78.0% and 77.5% accordingly. This is more, than in sample № 1, and is associated with introduction into formulations of eggshell, beet and carrot powders, which improve structural and mechanical properties and, as a result, porosity of baked products;
- samples № 2 and № 3 are enriched with cellulose and fill 10% from its daily need.

4. Conclusions

As a result of the work, the bakery products with amaranth, which are enriched with proteins, calcium and β-carotene were developed.

Amaranth both in natural (seeds) and processed (flour) forms enriches obtained products with protein, vitamins and minerals. Lysine contained in amaranth determines the relevance of using eggshell, beet and carrot powders of IR-drying in bakery products formulations enriched with amaranth.

Dry demineralized whey enriches nutritional and biological value of bakery products with lactose and other useful substances and helps to intensify the dough kneading process.

Eggshell, beet and carrot powders enrich bakery products with calcium, vitamins, cellulose, mineral elements and antioxidants and improve their porosity. Considering the physiological daily need for protein and calcium, samples № 2 and № 3 fill 14% and 15% from protein and calcium daily need accordingly. Regarding the physiological need for β-carotene, sample № 3 fills 15% from β-carotene daily need.

It has been found that the accelerated mechanical treatment of dough reduces its preparing time.

Therefore, due to the biological value and chemical composition of amaranth, eggshell and vegetable powders, bakery products enriched with them have high potential for improving human health and preventing diseases.
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