Amaranth as a Non-Conventional Bakery Crop from the Standpoint of Food Security

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Abstract. This paper investigates the possibility of using amaranth grains to ensure the food security and provide healthy nutrition in the Far Eastern Federal District. It proposes growing amaranth in Primorsky Krai to make flour that could be used in baking. Replacing 10% of wheat flour with amaranth flour improves the quality of wheat bread while also enhancing its biological and nutritional value.

1. Introduction
Food security means every person at any time has access to, and can afford, enough food that is safe and sufficient for an active and healthy lifestyle.

To address the dietary problems in Russia, this paper proposes altering its structure by supplementing the menu with functional foods that would help meet the body’s physiological demand for nutrients and energy [1, 2].

The environmental degradation in many countries deteriorates the environment and the foods. Excessive radioactive contamination calls for finding, developing, and adopting preventive foods that could help remove heavy metals and radionuclides from the human body. In this regard, it seems appropriate to expand the range of foods rich in special substances capable of removing heavy and radioactive metals from the body.

Given how exceptionally important bread is for the human diet, enriching it with functional supplements that have curative or preventive properties has become a popular research topic [3, 4].

Plant materials, including underutilized non-conventional plants, seem interesting and promising for making functional foods.

It is of both theoretical and practical interest to design novel functional bakery products based on amaranth flour as a non-conventional plant material available in Primorsky Krai.

Amaranth (Lat. Amaranthus L.) is a widespread genus of mainly annual herbaceous plants distinguished by small flowers making spiciform-paniculate inflorescences. Amaranth seeds have high nu-
tritional value. Flour, starch, bran, and oil can be produced from such seeds. Depending on the variety, they are 14% to 20% easily digestible protein, 6% to 8% vegetable oil with a high concentration of polyunsaturated fatty acids and biologically active components, 60% starch, vitamins A, B, C, E, and P, as well as carotenoids and pectin; besides, they are also rich in macronutrients and micronutrients, especially calcium and iron. Lipids are 77% to 83% triglycerides [5, 6]. Amaranth features a uniquely composed protein that is well-balanced in amino acids, some of which are irreplaceable, making it even more valuable. Albumins and globulins constitute over a half of this protein. The fat contains oleic, linoleic, and linolenic acids; up to 10% of the lipid fraction is squalene, the main precursor of triterpenes and steroids including sterols and their derivatives that are used in the treatment of atherosclerosis [7, 8, 9].

Up to 10% of the above-ground portion of the plant is pectin; the grain contains insoluble protopectin. These substances are used in the food industry and in healthcare to remove heavy metals and radionuclides from the human body [10].

Thanks to two important antioxidants it contains, namely vitamin A and carotene, amaranth boosts insulin secretion, making it recommendable as a food for diabetic patients and for use in making specialized dietary products and general-purpose food formulas [11]. On the other hand, amaranth is poor in gluten, further improving its value for allergic patients and coeliac patients [12].

Amaranth-based products are crucial for vegetarians, as they help increase the intake of proteins and other nutrients a meat-free diet would otherwise lack. All these aspects have been covered and reflected in a variety of studies and projects. In the late 1980s, the Ministry of Higher Education of the Russian Soviet Federative Socialist Republic founded its Amaranth Program [13, 14, 15].

The goal hereof was to test the feasibility of using whole-grain flour of amaranth grown in Primorsky Krai for making wheat bread.

2. Materials and methods

Research was carried out by the bakery shop of the Student Meal Factory, Federal State Budgetary Educational Institution of Higher Education Primorskaya State Academy of Agriculture (‘Primorskaya Academy).

The following components were used in research: high-grade wheat flour per GOST 26574-2017 [16]; instant yeast per GOST R 54845-2011 [17]; table salt per GOST R 51574-2018 [18]; sunflower oil per TR TS 024/2011 [19]; drinking water per GOST R 51232-98 [20]; and amaranth flour per TU 9293-006-18932477-2004 [21]. All the ingredients were in line with corresponding standards or specifications.

Specimens were made from a single batch of the raw materials. The research team tested the finished products for acidity per GOST 5670-96, moistness per GOST 21094-75, and porosity per GOST 5669-96. Porosity testing was performed per GOST5669-96 using a Zhuravlyov probe. Wt.% of moisture was evaluated per GOST 21094-75 by an express method using a Chizhova device.

Amaranth bread was designed by the following algorithm: (1) formulation development; (2) baking to optimize the formulation; (3) quality testing; (4) calculating the energy value, the fats, the proteins, and the carbohydrates.

To produce the flour, the research team used the Kharkiv variety grown in the experimental field of Primorskaya Academy. Grains were ground using a laboratory mill and then sieved through a sieve made of metal fabric.

Five different formulations were tested to optimize the quantity of added amaranth flour.

Formulation 1: 100% wheat flour (the control formulation).
Formulation 2: 10% amaranth flour.
Formulation 3: 20% amaranth flour.
Formulation 4: 30% amaranth flour.
Formulation 5: 40% amaranth flour.
The control formulation used high-grade wheat flour and was a white bread formulation per GOST 26987-86 *White bread from wheat flour of high, first and second grades. Specifications*. The resulting loaf weighed 0.5 kg.

The dough was straight, i.e. all the components per the formulation were mixed in a single kneading. The process consisted of the following steps: prepare the raw materials, prepare the dough, cut the dough, bake, cool down, and store.

Dough pieces were placed in metal pans that were then put into a cupboard for 50 minutes at 40°C and 65% relative humidity for proofing. Bread was based over 50 minutes at 200°C.

3. Results and discussion

High humidity makes bread less nutritionally valuable and less tasty while also reducing its shelf life. As a rule, higher flour grades require lower humidity.

However, adding amaranth to wheat flour improves its saccharifying and gasifying power. Besides, it also boosts yeast fermentation. Acids accumulate at a faster rate, meaning that the semi-finished product ripens faster.

If the wheat-flour gluten is not strong enough, adding amaranth flour might make bread less stable and porous. This might be the reason why the bread produced in this research had a lower porosity. The greatest porosity was observed in the control bread, see Table 1.

| Table 1. Physical and chemical indicators of bread quality. |
|------------------------------------------------------------|
| Formulation      | Crumb moisture, % | Crumb acidity number | Porosity, % |
| Formulation 1: 100% wheat flour (the control formulation) | 44.0            | 3.0                          | 71.0        |
| Formulation 2: 10% amaranth flour | 44.2            | 2.9                          | 65.3        |
| Formulation 3: 20% amaranth flour | 44.4            | 2.8                          | 64.2        |
| Formulation 4: 30% amaranth flour | 44.6            | 2.8                          | 57.8        |
| Formulation 5: 40% amaranth flour | 45.1            | 2.5                          | 55.4        |

As shown in Table 1, having more amaranth flour made the crumb moister, less acidic or porous; however, all the indicators were within the acceptable limits.

Appearance-wise, all the resulting loafs were stable in shape. They all had a smooth surface, no fractures or oven breaks as long as amaranth flour accounted for no more than 20% of the total composition. The crust were uniformly brown-colored. The control and Formulation 2 produced a good porosity. Formulations 4 and 5 had a lower specific weight.

The bread featured homogeneous fine thin-walled porosity, no hollows, the crusts were up to 3 mm thick. No foreign inclusions observed.

Bread was generally in line with the taste and smell expected from this category of bread; however, amaranth flour did boost the specific taste and smell of amaranth. Table 2 shows the organoleptic indicators of the product.
Table 2. Organoleptic indicators.

| Quality indicator | 100% wheat flour (the control formulation) | Amaranth flour, % | 10 | 20 | 30 | 40 |
|-------------------|--------------------------------------------|------------------|----|----|----|----|
| Shape             | Matching that of the pan, no lateral leaks | Matching that of the pan, no lateral leaks | Pronounced deformations and irregularities | Pronounced deformations and irregularities |
| Crust surface     | Smooth, no fractures or oven breaks, not burnt | Smooth, no fractures or oven breaks, not burnt | Smooth, deformed | Smooth but oven-broken |
| Color             | Light brown | Uniform, dark brown | Uniform, dark brown | Uniform, dark brown |
| Well-cooked?      | Yes | | | |
| Mixing            | No traces of bad mixing | Good | Typical of this bread category | Too fine | Too fine | Too fine |
| Porosity          | Good | Typical of this bread category with a slight smell and taste of amaranth | Typical of this bread category, pronounced amaranth taste | Typical of this bread category, pronounced amaranth taste | Typical of this bread category, pronounced amaranth taste | Typical of this bread category, pronounced amaranth taste |
| Taste and smell   | Typical of this bread category | Too fine | | | | |

Thus, keeping amaranth flour within 20% produced the best organoleptic quality.

The energy value was calculated using the tables from I.M. Skurikhin’s Chemical Composition of Russian Foods [Rus: Химический состав российских пищевых продуктов] [23]. Protein, fat, and carbohydrate content of each bread was calculated on the basis of the net content the tables specified for each ingredient. The resulting figures were multiplied by the digestibility factors: 84.5% for proteins, 94% for fats, and 95.6% for carbohydrates.

Table 3 shows the energy value of the control bread versus the best bread (10% amaranth flour)

Table 3. Energy value of bread.

| Formulation                | Content, g | Energy value, kcal/kJ |
|----------------------------|------------|-----------------------|
| 100% wheat flour (the control formulation) | 6.3 | 204/852.7 |
| Formulation 1: 10% amaranth flour | 7.6 | 198/827.6 |

Apparently, 10% amaranth flour bread had a better nutritional value. This formulation produced 1.3 g more proteins and 0.1 g more fats per 100 g of product.
4. Conclusions
Primorsky Krai’s agricultural and climatic conditions are suitable for producing amaranth grains; flour made from them does improve the nutritional value of bread and enriches it with valuable bioagents. Having more amaranth flour made the crumb moister, less acidic or porous; however, all the indicators were within the acceptable limits. The control was the best bread organoleptically; however, 10% amaranth bread was not bad either. Further promotion of the product will require marketing and advertising.

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