IOP Conference Series: Earth and Environmental Science

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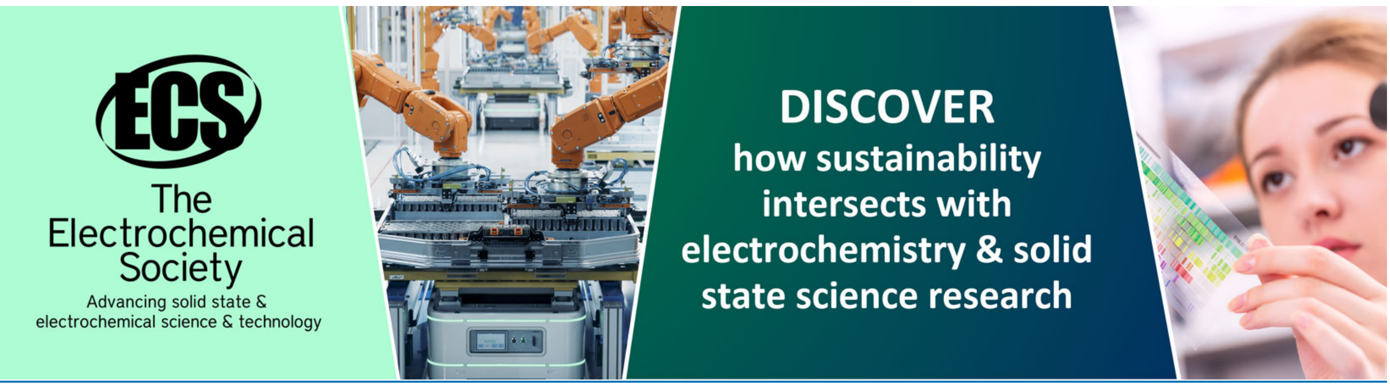
To cite this article: N M Derkanosova *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **422** 012010



Application of the amaranth extrudate in the technology of bread from grade wheat flour

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Abstract. Bakery is products whose composition regulation can have a beneficial effect on the country population's diets. Among many enriching ingredients amaranth can be distinguished as promising raw materials. Its processed products can act as a basis for the gluten-free food manufacturing or as an ingredients enriching with protein, dietary fiber, squalene, polyunsaturated fatty acids and other nutrients. At the same time, integrated use of the amaranth grain potential should be recognized as the most appropriate. In the article, it was proposed to use ground extruded amaranth Universal as an enriching raw material ingredient for bakery products. The dosage limits of the amaranth extrudate were determined by a technique for calculation the structure of a multicomponent baking mixture for the production of enriched products. The technique includes the statement of the task of calculating the components of the mixture in the form of a stochastic programming problem in the M-statement. Accordingly, the mathematical expectation of the objective function value is optimized for given values of the coefficients variation and the probability of constraints fulfilling. In dosages justified by preliminary calculations, amaranth extrudate is introduced into model mixes with first-grade wheat flour to determine their baking properties. The indicators of the complex strength characteristics of the model mixtures are determined on the valorigraph. Results showed a decrease in baking properties with an increase in the mass fraction of amaranth extrudate in model mixtures up to 30%. At the same time, the numerical value of the valorimetric assessment allows us to consider this dosage of enriched bakery product formulations by introducing the extruded amaranth Universal.

1. Introduction

Provision of good nutrition, disease prevention, increasing the duration and improving the life quality for the population are aspects laid down in the "Strategy for improving the food quality in the Russian Federation until 2030". Declared values can be fully extended to any geographical and economic territory. It is known that "nutrition is one of the most important factors, which determines health of the population. Proper nutrition defines the normal growth and development of children, helps to prevent diseases, prolongs life, increases working capacity and creates conditions for adequate adaptation to the environment" [1,2]. Discussing the nutrition problem within the framework of prospects for the diets correction, it should be noted that one of the most favorable ways is the development of enriched bakery products. Bread is a product of mass and daily consumption by all age groups of the population. Its correction through the adding of enriching raw materials and, therefore, functionally demanded ingredients will increase the consumption value of currently deficient dietary fiber, minerals, polyunsaturated fatty acids and other nutrients. As part of the implementation of this area, quite a lot of attention has recently been paid to amaranth and its processed products. In this case, there are two directions. The first is using of amaranth as the main ingredient in products which belongs to the specialized category "with low or no separate amino acids", and the second - as enriching with protein, squalene, minerals, vitamins, alimentary fiber and other nutrients [3,4,5,6,7]. Often in the research they propose to use the processed amaranth products - flour or oilcake - a secondary product of amaranth oil. While the whole amaranth grain is characterized by a high content of alimentary fiber and other nutrients, the rational use of which may be associated with the production of its processed products. As such, it is proposed to obtain an extruded product from whole grain amaranth with its subsequent application in the technology of bakery products [8]. At the same time, the problem of preserving the traditional sensory characteristics of products obtained with the use of new raw materials remains an important issue, as numerous marketing studies demonstrate commitment to it. In this connection much attention is given to studying the effect of extruded amaranth on the baking properties of flour, as a determining factor in the formation of the quality of bakery products.

2. Materials and methods

In the experimental part of research grain amaranth grown in the collection nursery of the Voronezh State Agrarian University was used. By geographic location, the nursery is located in the forest-steppe zone of the Central Chernozem Region. The soil of the experimental plot is leached medium loamy chernozem. Its availability of mobile forms of nitrogen, phosphorus and potassium is medium and high. Humus content is equal to 4.5%, pH is fluctuated from 5.4 to 5.8. The total rainfall for a period with a temperature above +10 ° C is 250-260 mm. The total amount of active temperatures is 2581 ° C. Sowing was carried out in the second half of May.

Amaranth grain composition was determined by standardized methods at the accredited research center of the All-Russian Scientific Veterinary Institute for Pathology of Pharmacology and Therapy: moisture content - according to GOST 13586.5-2015, mass fraction of protein - according to GOST 10886-91, fat - according to GOST 29033-91, fibre content - according to GOST 31675-2012, total sugar - according to GOST 15113.6-77, ash content - according to GOST 27494-2016, phosphorus content - according to GOST 26657-97, calcium - according to GOST 26570-95, carotene - according to GOST 13496.17-95 , copper, zinc - according to GOST 30692-2000, iron, manganese - according to GOST 32343-2013. Previously, there were series of determining the composition of the amaranth of varieties of the Voronezh selection and selection of the FSBSI “Federal scientific center of vegetable growing”: Voronezh-36, Voronezh, Emperor, Rubin, Universal, Gigant, Dobrynya and Valentina. For the further research amaranth variety Universal was selected for a number of indicators. The chemical composition of grain of the Universal variety is given in Tables 1 and 2.

Table 1. Composition of amaranth grain Universal

Amaranth grade	Fraction content, %					
	moisture	protein	fat	cellulose	common sugar	ash
Universal	9.46	26.47	13.81	8.9	4.10	8.08

The whole Universal grain was extruded on a laboratory universal small-sized extruder (EUSS-1) at a temperature of 110-120 ° C. The gotten extrudate was crushed to a particle size of 125 μm and less.

Table 2. Composition of the amaranth Universal mineral substances

Amaranth grade	Content					
	phosphorus, %	calcium, %	copper, mg/kg	iron, mg/kg	zinc, mg/kg	manganese, mg/kg
Universal	0.63	0.36	12.98	90.0	30.89	44.88

The amaranth extrudate is a dry powdery semi-finished product, light cream in color with a nutty flavor and a faint bitter taste which characterize amaranth. It contains 4.76% of moisture, 27.51% of protein, 4.53% of fat and 3.20% of fiber.

To study the effect of extrudate on the baking properties of flour, model mixtures with first-grade wheat flour were compiled. The choice of first grade flour was made due to lower requirements for the color of the finished product on the one hand and on the other hand, it has high gluten content and, accordingly, the possibility of introducing a larger amount of gluten-free ingredient. Studies of the mixtures were realised in the laboratory of Scientific Research Institute of Agriculture of Central Chernozem zone named after V.V. Dokuchaev. Processing of the results was carried out in accordance with GOST R 51414-99 "Wheat flour. Physical characteristics of the dough. Determination of water absorption and rheological properties using a valorigraph". The quantity and quality of gluten in model mixtures was identified according to GOST 27839-2013.

3. Results and Discussion

To determine the boundary values of the introduction of amaranth extrudate relatively to the first-grade wheat flour at the beginning of research we used the results obtained previously by mathematical methods. Methodology for calculating the structure of a multicomponent baking mixture for the production of enriched products, taking into account the instability of the nutrient content, were applied [9]. The method includes the statement of the task of calculating mixture components in the form of a stochastic programming task in the M-statement, i.e. mathematical expectation of the objective function value is optimized for a given sample of the coefficients and the probability of fulfilling the constraints.

Mathematical model of the task provided for the determination of the objective function, constraints and boundary conditions. The objective function characterizes the content of a certain nutrient in the mixture, as a rule, the maximum of the objective function is determined. Micro- and macronutrients can be considered as such agents; their list corresponds to [10]. In our studies, the nutrient content of the target function was taken as alimentary fiber content. The desired values of the variables x_j are the components fractions. Consequently, the coefficients c_j in the objective function are laboratory-determined nutrient contents in the mixture components. The first limitation is logical for this task formulation and is associated with the calculation features for the bakery products recipe compositions: the fractions of grain components sum is equal to one. The second group of restrictions is associated with technological requirements for the mixture baking properties and consumer preferences. Only certain baking properties of the flour mixture can ensure the quality of the finished product and, accordingly, satisfy the consumers' requirements for the finished products sensory characteristics.

If the quantities a_{ij} and b_i included in the constraints are random, then the i-constraints are written as follows:

$$P\left[\sum_{j=1}^{n} a_{ij} x_j \le b_i\right] \ge \alpha_i \quad , \tag{1}$$

where α_i is given probability with which the i-restriction must be fulfilled.

Combining the objective function, constraints and boundary conditions, we formulated M-statement of the stochastic programming task [11, 12, 13] as the goal of composing a mixture while maximizing the average value of the objective function (2); n is the number of mixture components, m is the number of restrictions:

$$\begin{cases} M[F] \to \max, \\ \sum_{j=1}^{n} x_j = 1, \\ P\left[\sum_{j=1}^{n} a_{ij} x_j \le b_i\right] \ge \alpha_i, \\ d_j \le x_j \le D_j, \quad i = \overline{1,m}, \ j = \overline{1,n} \end{cases} \tag{2}$$

For the task (2), the deterministic equivalent was used:

$$\begin{cases} F = \sum_{j=1}^{n} M[c_j] x_j \to \max, \\ \sum_{j=1}^{n} M[a_{ij}] x_j + t(\alpha_i) W_i \le M[b_i], \\ W_i = \sqrt{\sigma^2 [a_{ij}] x_j^2 + \sigma^2 [b_i]}, \\ \sum_{j=1}^{n} x_j = 1, \quad d_i \le x_j \le D_j, \\ i = \overline{1,m}, \qquad j = \overline{1,n}. \end{cases} \tag{3}$$

Here α_i is given probability levels, $t(\alpha_i)$ is the reciprocal of standard normal distribution Wi characterizes the variations of a_{ij} and b_i (σ^2 are the variances of a_{ij} and b_i respectively). In the case of deterministic source data $W_i = 0$.

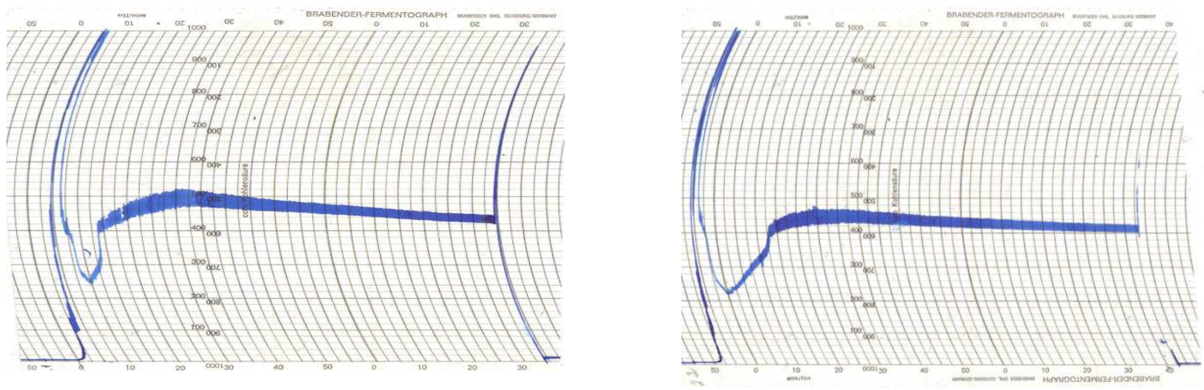
In the research there was introduced technological restrictions of the gluten content in flour mixture.

The results of modeling and analysis of optimal solutions using the example of calculating the structure of a flour mixture with an enriching component - whole-ground amaranth flour as a source of alimentary fiber and polyunsaturated fatty acids allowed us to introduce an upper limit on the dosage of the product of processing whole grains of amaranth - not more than 30% by weight of the flour mixture.

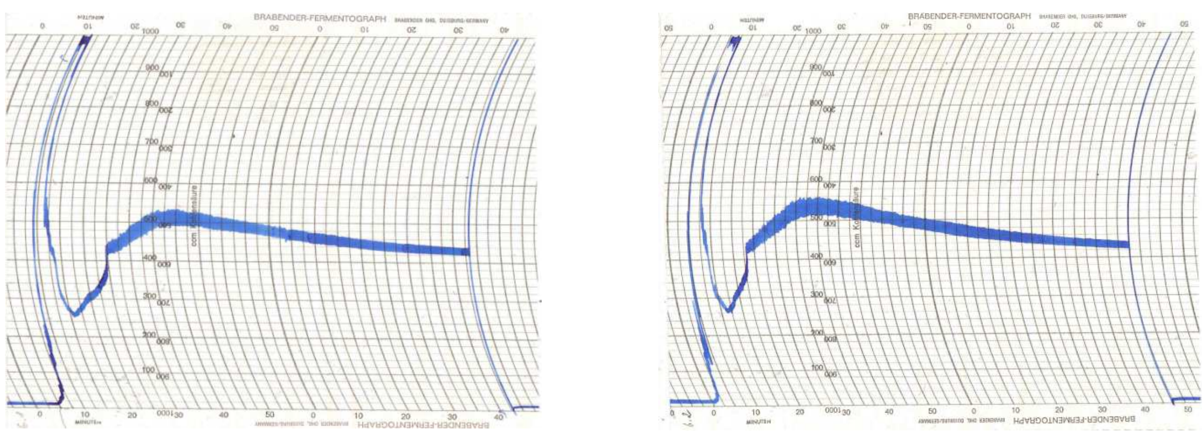
20% of enriching component are able to ensure the bakery quality in accordance with established regulatory requirements. Adding 30% of the processed whole-ground amaranth in the product will lead to decrease of the finished products quality. At the same time, consumers for the sake of product usefulness are ready to make such a concession. So, further experimental series was aimed at establishing the change degree of baking properties and predicting the quality of bakery products with extruded amaranth.

Accordingly, in studies of the effect of crushed amaranth extrudate on the baking properties of first-grade wheat flour, model mixtures of flour and extrudate were prepared respectively in mass fractions 90:10, 80:20, 70:30.

The research results are presented in Figure 1 and Table 3.



a)



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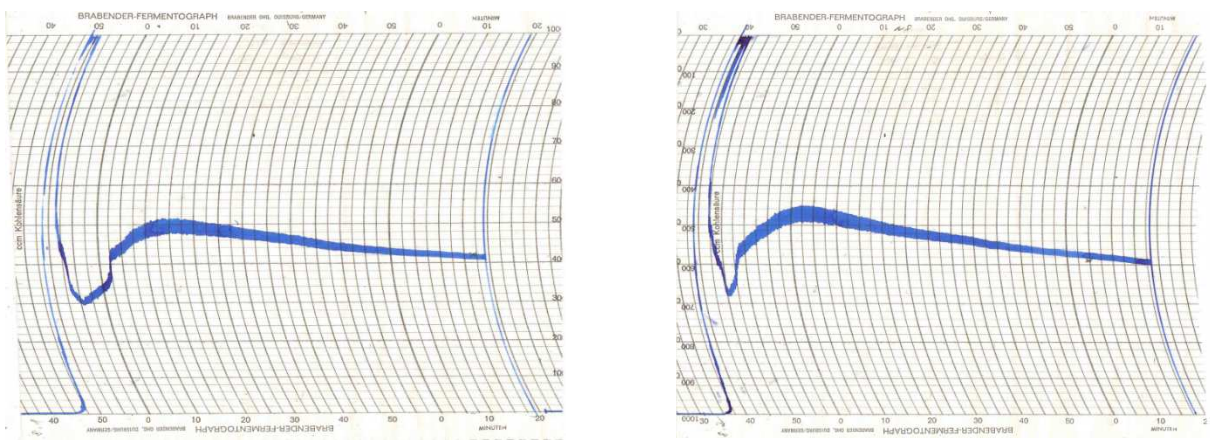

c)

Figure 1. Farinograms of flour mixtures with the ratio of wheat flour of the first grade and amaranth extrudate in mass fractions: a) 90:10; b) 80:20; c) 70:30. On the left - repetition number 1, on the right - repetition number 2.

Table 3. Indicators of the integrated strength characteristics of model mixtures

Indicator	Characterization of the model mixture with the ratio of first-grade wheat flour and extrudate from whole amaranth grain in mass fractions		
	90:10	80:20	70:30
Water absorption capacity, %	64.3	64.7	64.5
Duration of dough formation, min	4’ 45”	4’ 45”	4’
Dough stability, min	2’ 40”	2’ 20”	2’ 10”
Liquefaction, conv. unit	60	80	85
Valorimetric evaluation, conv. unit	65	63	60

As shown by studies results, the water absorption capacity of the flour mixture within the 30% dosage of amaranth extrudate is approximately at the same level. Apparently, a decrease in the proportion of gluten proteins and, accordingly, their ability to connect water is compensated by a more active binding of water to alimentary fiber of extrudate. Probably, partially gelatinized during extrusion amaranth starch affects. Decreasing of the dough formation time and, especially, an indicator of its dilution confirm the latter argument. With an increasing of the dosage of the extrudate, the dough stability, which characterizes the duration of preservation by the dough of the maximum level of consistency during mixing, decreases. The general regularity is preserved according to the results of valorimetric evaluation. Generally, at the level of average quality, a tendency is observed to quality decrease with an increase in the mass fraction of amaranth extrudate in the model mixture.

4. Conclusion

Studies have shown a decrease of the baking properties of mixtures with amaranth Universal extrudate. In this case, the amaranth extrudate has a differentiated effect on the dough properties. Possibility of ensuring the finished products quality by adjusting the parameters of the kneading process and the maturation of the dough confirm it. A generalized valorimetric evaluation of the dough with adding 30% of amaranth extrudate is reduced by 8%, which generally allows us to consider this dosage in the recipe composition of bread enriched with alimentary fiber and polyunsaturated fatty acids.

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