EFFECT OF POP SORGHUM ON THE QUALITY OF GLUTEN-FREE CEREAL BARS

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ABSTRACT

Subject of research: technology for the production of gluten-free cereal bars
Investigated problem: the development of gluten-free bars with an improved recipe composition, enriched with biologically valuable substances, in particular, for people suffering from gluten intolerance.
Main scientific results: Changes in the amino acid composition of sorghum grain due to microwave processing were determined. Formulations of cereal bars were developed using the following ingredients: bananas, dates, coconut flakes, buckwheat flakes, almonds, flax seeds, sorghum pop sorghum, vanilla sugar. The advantages of the biological value of pop sorghum as a promising ingredient in bars were revealed. The influence of the content of pop sorghum in the amount of 4, 6, 8 % in the recipe of cereal bars on their organoleptic and structural-mechanical properties was determined, the nutritional and energy value of the products was established. It was revealed that the introduction of pop sorghum into the composition of the recipe for cereal bars had a significant effect on the maximum load, deformation at maximum load and the coefficient of elasticity of bars. Practical recommendations on the recipe composition of gluten-free cereal bars for pop sorghum and technological modes of their production were developed.
The area of practical use of the research results: food enterprises for the production of snacks and functional products, in particular, food concentrate enterprises, restaurants, craft food production.
Innovative technological product: technology for the production of gluten-free cereal bars with the addition of pop sorghum
Scope of application of an innovative technological product: manufactures engaged in the production of functional food products with high nutritional value in a relatively small volume are an excellent source of energy, dietary fiber, vitamins, macro- and microelements for the human body, in particular, consumers suffer from gluten intolerance.

1. Introduction

1. 1. The object of research

In the field of multifunctional food products, cereal bars occupy a special place. The growing demand for cereal bars is due to the fact that these products can meet people's needs for quick and convenient eating. But such products need to improve the recipe composition and, accordingly, the technology for their manufacture, through the use of biologically valuable raw materials. Therefore, the object of research is the technology of gluten-free bars enriched with pop sorghum obtained by microwave processing.

1. 2. Problem description

Cereal bars are obtained from whole or processed cereal grains with the addition of dried fruits, dried berries, nuts or seeds, streams, honey, sugar and other components [1]. The advan-

tages of cereal bars include high nutritional value (energy value) with a relatively small size. This leads to the rapid saturation of the body with nutrients. Low humidity and water activity, in turn, ensure a long shelf life of the product, compactness and the possibility of a convenient snack on the road.

The global bar market is fast growing, at 11.7 billion USD in 2018–2019. [2], and the greatest demand for cereal bars is observed in the USA and England [3]. To improve the nutritional profile of cereal bars, it is suggested to use oat and wheat flakes [4], seeds of flax, sunflower and their processed products [5], berries, fruits, nuts [6] or sprouted grains [7]. The formulations of bars with the addition of amaranth seeds and dried fruits of black chokeberry [8], puffed rice [9] have been developed. But most scientific research has focused on the use of gluten-free raw materials, limiting the consumer market for gluten intolerant bars. Unfortunately, the number of such consumers is steadily growing and, according to the latest data, reaches from 1 to 7 % of the world's population [10]. In particular, it has been proposed to use quinoa seeds [10] or pop amaranth [11] for the production of gluten-free bars. But the use of pop sorghum as a biologically valuable raw material in the technology of cereal bars is not given due attention.

Among cereals, sorghum has the highest polyphenol content. Phenolic acids in sorghum are mainly in the form of formic acid derivatives or cinnamic acid derivatives, usually present in free or bound form, and are mainly found in the outer shell of the sorghum caryopsis [12]. Therefore, for the production of multifunctional goods, it is advisable to use grain without removing the fruit shell. In the work of Meison S. [12] it was found that heating causes an increase in the level of all detected phenolic acids (except for free vanilla and bound p-coumaric acid), which is due to the release of bound phenolic compounds from the cell walls and the breakdown of conjugated polyphenols. It has been proven that after microwave processing of pop sorghum, the content of soluble polyphenols increases by 39 %, and that of bound polyphenols decreases by 42 % [13], which is positive for increasing the bioavailability of such food components. The issue of assessing the amino acid composition of grain as a result of processing deserves special attention.

There has been limited development of wholesome gluten-free bars with high consumer value for people with gluten intolerances. The formulations of such products require improvement due to the introduction of biologically valuable raw materials.

1. 3. Suggested solution to the problem

The search for new raw materials for the enrichment of bars with biologically active substances is urgent. The processed products of wheat, corn, rice as traditional crops have a composition depleted in polyphenolic substances, an insufficient amount of essential amino acids. Sorghum grain is a gluten-free raw material containing phenolic acids, procyanidins and flavonoids. Grains of certain varieties of sorghum have so-called pop-properties, which makes it possible to obtain from it an easily digestible product – puffed grain [14], which is an excellent basis for the production of cereal bars.

As the number of people suffering from gluten intolerance is growing, pop sorghum itself is a promising raw material for the production of cereal bars. To substantiate the ways of its use in the technology of cereal bars, it is necessary to identify the features of its amino acid composition and functional and technological properties as an ingredient in cereal bars.

The aim of research. The aim of research is to determine the amino acid composition of pop sorghum obtained by microwave processing and the effect of pop sorghum on the formation of organoleptic, nutritional, structural and mechanical properties of gluten-free cereal bars.

2. Materials and methods

To obtain pop sorghum, grain sorghum of the Fulgus variety (**Fig. 1, *a***), grown in Ukraine, was used. Sorghum grain was subjected to microwave processing to obtain an airy product (**Fig. 1, *b***).

The amino acid composition of sorghum grain before and after microwave treatment was analyzed by the method of ion exchange liquid column chromatography using lithium citrate buffers as eluents on an automatic amino acid analyzer T 339 (Mikrotekhna, Czech Republic). The ninhydrin detection method was used to register amino acids in the eluents.

Bananas, dates, coconut flakes, buckwheat flakes, almonds, flax seeds, pop sorghum, and vanilla sugar were used to formulate the gluten-free cereal bars. Pop sorghum was added to the composition of cereal bars in the amount of 4, 6, 8 % in the total mass of other recipe components for the test samples. The functional diagram of the production of bars is shown in **Fig. 2.**

a *b*

Fig. 1. Grain of sorghum of the Fulgus variety: *a* – native; *b* – after microwave processing

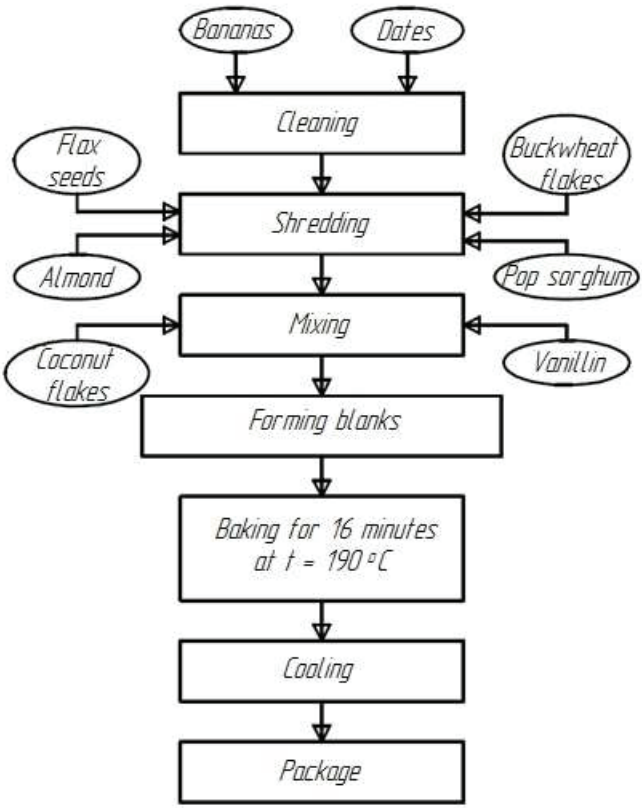


Fig. 2. Functional diagram of the production of gluten-free cereal bars

For sensory assessment, the significance indicators were determined by an expert method with the participation of five experts. Among the indicators, the shape, color, odor, appearance in the break, taste, chewiness were determined. The significance coefficients were 0.8, 1.3, 2.1, 0.8, 2.9, 2.1, respectively.

Structural and mechanical properties were determined on a texture analyzer developed at the Dnipro State Agrarian and Economic University (Dnipro, Ukraine) (**Fig. 3**) using a bending test indenter. The following indicators were determined: F max – maximum load, N; Δx – deformation at maximum load, m; k – coefficient of elasticity, N/m. Analyzes were carried out in 3–5 repetitions.

Fig. 3. Texture analyzer for determining the structural and mechanical properties of food

3. Results

As a result of heat treatment, changes in the amino acid composition of food products occur. The results of studying the effect of microwave treatment (microwave treatment) on the amino acid composition of sorghum grain are given in **Table 1.**

Table 1

Amino acid composition of sorghum grain before and after microwave treatment

Amino acid	before microwave treatment			after microwave treatment		
	mg/100 g	% by mg	score, %	mg/100 g	% by mg	score, %
Alanin	0.56	8.5	–	0.69	6.1	–
Arginine	0.24	3.7	–	0.39	3.5	–
Aspartic acid	0.43	6.6	–	0.76	6.7	–
Valine	0.26	4.0	79	0.51	4.5	90
Histidine	0.13	1.9	–	0.23	2.0	–
Glycine	0.26	4.1	–	0.56	4.9	–
Glutamic acid	1.50	23.1	–	2.95	26.2	–
Isoleucine	0.19	3.0	74	0.40	3.6	90
Leucine	0.90	13.8	197	1.79	15.9	227
Lysine	0.16	2.4	43	0.17	1.5	28
Methionine	0.13	2.1	–	0.18	1.6	–
Proline	0.70	10.7	–	0.62	5.5	–
Serine	0.29	4.4	–	0.55	4.9	–
Tyrosine	0.20	3.1	138	0.44	3.9	158
Threonine	0.18	2.8	71	0.37	3.3	82
Phenylalanine	0.33	5.1	–	0.64	5.6	–
Cystine	0.05	0.8	83	0.03	0.3	53
Total	6.51	100	–	11.27	100	–

It has been found that the total amino acid content in pop sorghum obtained by microwave treatment increased by 73 %. In particular, an increase in essential amino acids was found, which were determined during the study. Thus, there was an increase in the content of valine and threonine by 98 and 100 % in comparison with the native grain, which may explain the appearance of a sweet taste in the puffed product after microwave treatment. It is these amino acids that have a sweet taste, like serine, which also increased by 91 %. It has been revealed that the content of glutamic acid doubled, which, as it is known, acts as a stimulant to enhance human taste. A significant increase was also experienced in the content of leucine and isoleucine (2 times each). The phenylalanine content increased by 90 % and the methionine content increased by 35 %.

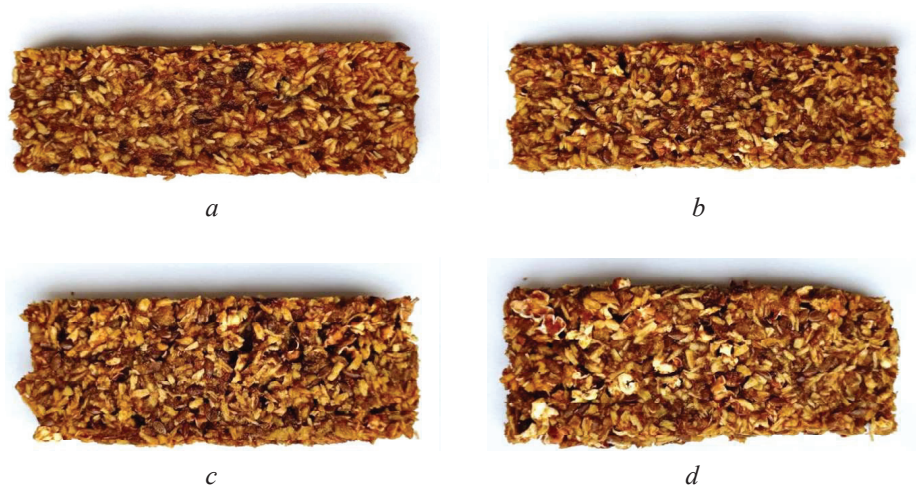
An 11 % increase in the content of lysine in the grain of sorghum after processing, which is related to the limiting amino acids of grain of cereals, has been established. The conditionally essential amino acids arginine and histidine in popped sorghum have an increased content of 64 and 82 %, respectively. Popped sorghum also increased the amount of alanine (by 24 %), glycine (by

110 %), aspartic acid (by 50 %) and tyrosine (by 115 %). At the same time, there was a decrease in the content of certain amino acids. Thus, the content of cystine decreased by 50 %, and the amount of proline were decreased by 11 %.

It has been found that lysine is the first limiting amino acid in sorghum grain both before and after microwave treatment. A decrease in the amino acid rate for lysine was recorded by 35 %, and for cystine – by 34 %. At the same time, the amino acid rate of all other essential amino acids increased after microwave treatment, which positively affects the biological value of pop sorghum protein.

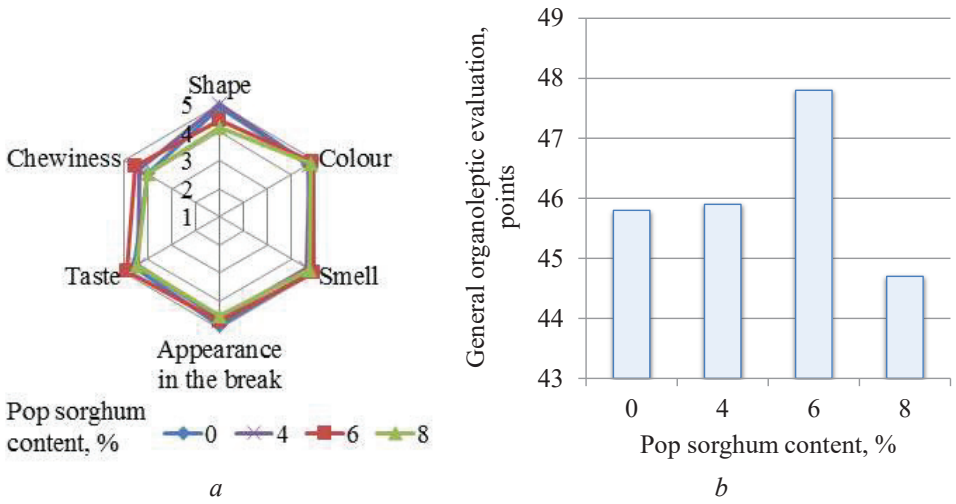
The introduction of cereal bars into the composition of the developed basic formulation significantly affected their quality. The appearance of the obtained bars is shown in **Fig. 4.** The recipe mixture of the control cereal bars had a uniform consistency, the product formed uniformly and kept the desired shape, the mixture did not crumble, and did not burn during baking. But to improve the taste and chewiness, it was advisable to introduce pop sorghum into the recipe. With the addition of 4 and 6 % pop sorghum, the mass became more fragile, which made it difficult to form the product. But in terms of organoleptic indicators of taste and chewiness, the quality increased significantly. When 8 % pop sorghum was added, the shape of the product was unstable and very fragile.

For the manufactured samples, a point organoleptic evaluation was carried out (**Fig. 5**).



a *b* *c* *d*

Fig. 4. Appearance of samples of gluten-free bars: *a* – without the addition of pop sorghum; *b* – with the addition of 4 % pop sorghum; *c* – with the addition of 6 % pop sorghum; *d* – with the addition of 8 % pop sorghum



a *b*

Fig. 5. Organoleptic evaluation of gluten-free cereal bars: *a* – profiles by descriptors, *b* – general organoleptic evaluation of products

According to data from **Fig. 5**, ***a*** it is possible to show that the bar with a 6 % pop sorghum content had the best chewiness and taste, while the color, smell, and appearance in the break was identical to the 4 % pop sorghum bar. At the same time, the shape of the bar containing 6 % pop sorghum deteriorated relative to the additive content of 4 %. The bar with 6 % pop sorghum received the highest organoleptic score. An increase in the dosage of the additive to 8 % led to both a deterioration in the shape of the products and their chewiness.

For prototypes of gluten-free cereal bars, the nutritional and energy value has been established (**Table 2**).

Table 2

Nutritional and energy values of gluten-free pop sorghum bars

Sample	% pop sorghum	Nutritional value indicator			
		Proteins, g	Fat, g	Carbohydrates, g	Energy value, kcal
1	0	20	67	369	456
2	4	21	65	378	464
3	6	22	62	386	470
4	8	23	60	393	477

It has been revealed that with the addition of pop sorghum to the recipe, the energy value increased and the fat content decreased. It is important that the use of pop sorghum contributes to the enrichment of products with phenolic acids and the improvement of the amino acid composition of products (**Table 1**)

Structural and mechanical properties are an important indicator of their quality. First of all, for such products, a critical indicator is their chewiness. Also, the structural and mechanical properties of the finished bars are important to ensure high-quality transportation of products. **Table 3** shows the results of the influence of the addition of pop sorghum on the structural and mechanical properties of the bars.

Table 3

The effect of the dosage of pop sorghum on the structural and mechanical properties of bars

% dosage of pop sorghum	Maximum load, F max, H	Deformation at maximum load, Δx, m	Elasticity coefficient, k, N/m
4	17.4±0.8	0.013±0.001	1199.8±69.6
6	24.4±0.4	0.015±0.001	1635.9±37.9
8	17.3±0.8	0.013±0.001	1295.5±57.9

It has been revealed that the structural and mechanical properties of the product differ significantly depending on the dosage of pop sorghum. So, the maximum load with an increase in the dosage of raw materials from 4 to 6 % in the formulation of products increases by 40 %. Moreover, among the samples, deformation at maximum load was also the highest for bars with 6 % pop sorghum. With an increase in the dose of pop sorghum to 8 %, there was a significant increase in the fragility of the products. According to the coefficient of elasticity, products made of 6 % pop sorghum had a statistically significant increase in the coefficient of elasticity by 36 and 26 % compared to bars containing 4 and 8 % pop sorghum, respectively.

4. Discussion

The study of the amino acid composition of sorghum grain before and after microwave treatment showed an increase in the content of free amino acids by 73 %, which has a positive effect on the biological value of pop sorghum. The increase in the content of free amino acids correlates with the data in [13], where an increase in the content of free phenolic acids was recorded as a result of heat treatment of sorghum. Amino acids and phenolic acids can be classified as biologically active substances, the increased content of which should be considered an additional advantage for using the pop product in the production of gluten-free cereal bars.

The sensory evaluation of the finished cereal bars showed a significant effect of the percentage of pop sorghum in the formulation. When pop sorghum was added to the recipe of cereal bars in an amount of 4–6 %, an improvement in the organoleptic properties of the product was recorded. It was found that an increase in the amount of pop sorghum up to 8 % leads to a violation of the integrity and the acquisition of a more fragile structure by the bars, which impairs their transportation and, accordingly, causes a decrease in their consumer qualities. It can be assumed that, in this case, the fragility of the bars is explained by the insufficient amount of the binder component. Further research is planned to change the percentage of bananas, dates and pop sorghum.

Evaluation of the structural and mechanical properties of the obtained cereal bars confirms that the introduction of pop sorghum into the product formulation has a significant effect on the maximum load, deformation at maximum load and the coefficient of elasticity. It has been established that when forming the optimal structural and mechanical properties of cereal bars, pop sorghum should be added to the experimental recipe in an amount of no more than 6 % by weight of raw materials.

It should be noted that this study limited the use of bananas, dates, coconut flakes, buckwheat flakes, almonds, flax seeds, pop sorghum, and vanilla sugar in gluten-free cereal bars. Expansion and subsequent enrichment of the recipe composition of the bars with such valuable raw materials as fat-free seeds of pumpkin, sesame, amaranth, millet would additionally enrich the products with cucurbitin, squalene, amarantin, miliacin [4, 7]. Prospects for further research should also be focused on determining the optimal dispersion of the introduction of pop sorghum into the product, the possibility of replacing it with extruded sorghum flour. Separately, it would also be advisable to differentiate cereal bars in accordance with consumer qualities and biological value by groups of specialized purposes.

5. Conclusions

The total amino acid content in popped sorghum is increased by 73 % after microwave processing of grain. Compared to native grain, the content of valine and threonine is increased by 98 and 100 %, respectively. The value of the amino acid rate is calculated. Lysine is the first limiting amino acid in sorghum grain before and after microwave treatment.

Formulations of gluten-free bars included bananas, dates, coconut flakes, buckwheat flakes, almonds, flax seeds, sorghum pop sorghum, vanilla sugar have been developed.

The 6 % pop sorghum bars has the best chewiness and flavor, and the color, smell and fracture appearance are the same as the 4 % sorghum bar. An increase in the amount of additives up to 8 % leads to a deterioration in the shape of the product and its chewiness.

The introduction of pop sorghum into the formulation of bars leads to an increase in their energy value due to an increase in the proportion of carbohydrates. The dosage of pop sorghum significantly influences the structural and mechanical properties of the product. The optimal property is the introduction of pop sorghum in the amount of 6 % by weight of the raw material.

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