Bulgarian Journal of Agricultural Science, 26 (No 3) 2020, 701–707

On the effectiveness of using topinambur powder in the recipe of grain bread

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Abstract

Naumova, N., Shtevyeva, K., Burmistrova, O. and Burmistrov, E. (2020). On the effectiveness of using topinambur powder in the recipe of grain bread. *Bulg. J. Agric. Sci., 26 (3)*, 701–707

There is currently a need to expand the variety of bakery products with a positive health effect and to advance the technologies and recipes for wholegrain bread to improve its physiological properties. The purpose of our research was to study the effectiveness of replacing high-grade wheat flour with topinambur powder in the recipe for wholegrain bread to increase the nutritional value of the final product. The objects of our research included high-grade baking wheat flour; topinambur powder; samples of semi-finished and finished "Tonus" bread from the "Fitness" line of white bread. Control samples were prepared according to a regulated recipe, experimental samples – by replacing 2, 4 and 6% of high-grade wheat flour with an identical amount of topinambur powder. Replacing 6% of the raw wheat with topinambur proved to be efficient due to the intensification of the fermentation processes of the semi-finished product, an increase in the mineral value of the wholegrain bread (the content of copper increased by 16%, phosphorus – by 12%, calcium, magnesium and iron – by 10%, zinc – by 11%, manganese – by 6%), an increase in the dietary fiber content, namely pectin, and the introduction of inulin polysaccharide into the product contrasted with a decrease in the gluten load on the human body.

Keywords: grain bread; wheat flour; topinambur powder; nutritional value

Introduction

When high-grade flour is produced, the useful substances contained in whole grains are separated and considered waste. Therefore, wholegrain products are used to increase the content of plant fibers, fats, and vitamins in baked goods (Kalmykova & Kalmykova, 2016; Syrbu, 2017). Thus, grain mixtures are a source of scarce and vital components for adequate human nutrition. However, there is a need to expand the variety of baked goods with positive health effects and to advance the technologies and recipes of wholegrain breads to improve the physiological properties (Makarova et al., 2016; Alekhina, 2018).

In recent decades, an excess incidence of diabetes has been noted worldwide. According to the Federal Register of Diabetes in Russia, at least 3–5% of the population has diabetes and up to 15% have symptoms of this disease (Dedov et al., 2017).

It is known that inulin polysaccharide is effective in treating not only diabetes, but also other diseases of civilization, namely, atherosclerosis, obesity, and various toxic effects. Up to 75% of the carbohydrate complex of topinambur consists of inulin polysaccharide, and also contains proteins (up to 7%), fats (0.3–0.7%), vitamins (B_1, B_2, C), pectin substances (up to 10%), fiber (up to 7%), organic acids, and macro- and microelements (Zhuk & Zelenkov, 1997; Roslyakov, 2014; Shanenko et al., 2016).

The use of topinamburs increases the concentration of iron in blood (Partoev, 2018), which is recommended for instances of increased physical and psycho-emotional stress,

decreased performance, and rapid fatigue (Shanenko et al., 2016). Prebiotic and radioprotective properties of topinamburs have also identified (Generalov, 2015; Pradhan et al., 2015; Samal, et al., 2015; Islamova et al., 2016).

There are known technologies of using topinambur powder in the production of various therapeutic baked goods: wheat bread (with the addition of 2–3% topinambur powder), cookies and biscuits (4–5% powder), rye-wheat bread, semi-finished products and finished products from wheat yeast dough (10% powder), etc. (Yermosh & Berezovikova, 2012; Umirzakova & Soltybaeva, 2012; Zhuravlev & Ladina, 2014; Soboleva & Sharykina, 2016; Gareeva & Nigmatyanov, 2018).

The purpose of the research was to study the effectiveness of replacing high-grade wheat flour in the recipe of wholegrain bread with topinambur powder to increase the nutritional value of the finished product.

Materials and Methods

The objects of our research included:

– high-grade baking wheat flour produced by Soyuz-Pischeprom Association (Russia, Chelyabinsk Region);

– topinambur powder produced by Topinambur (Russia, Tver region);

– model samples of semi-finished and finished products – "Tonus" bread from the "Fitness" line of white bread. Control samples were produced according to the prescribed recipe (Table 1): in experiment 1 – by replacing 2% of high-grade wheat flour with an identical amount of topinambur powder, and in experiment 2 and experiment 3 – 4 and 6%, respectively.

We used an accelerated dough-making method; the products were baked tinned with a net weight of 0.3 kg. The daily nutritional values for nutrients and biologically active substances were taken from the generally accepted recommendations (Tutelian, 2009).

Table 1. Recipe of "Tonus" grain bread

Raw materials components	Raw materials consumption, kg
High-grade baking wheat flour	50.00
"Fitness mix" baking wheat mixture	50.00
"Panifarin" complex baking improver	2.00
Compressed baking yeast	2.50
Salt	2.20
"Favorite" complex baking improving agent	0.50
Granulated sugar	3.00
Refined deodorized sunflower oil	2.00
Drinking water	as per calculations

Methods for studying the vegetable raw materials

The organoleptic characteristics of the materials were determined visually and during the test. The protein content was determined through sample mineralization using the Kjeldahl method; fat content – using the extraction method in a Soxhlet extractor; ash content – by complete combustion of the organic portion of the sample, followed by graphical determination of the studied parameter; phosphorus content – by the molybdenum-vanadium method; the content of the remaining mineral elements – by the flame atomic absorption method; fiber content – by hydrolysis and removal of protein and starchy substances with enzymes; pectin content – by the gravimetric method; and inulin content – by the method of high performance liquid chromatography. The microstructure was studied on a raster electron microscope. The moisture content of the topinambur powder was determined by first drying the raw material sample at 100°C for 4 hours to a constant mass followed by examination, the moisture of wheat flour was determined by drying the sample at 130°C for 40 min (Skurikhin & Tutelian, 1998; Magomedov et al., 2010).

Methods for studying the semi-finished products

Dough acidity was determined by titrating the prepared filtrate with sodium hydroxide solution (0.1 mol/dm^3) using 2-3 drops of phenolphthalein until obtaining a light pink color, which does not disappear within 1 minute, followed by examination. The content of yeast cells in the dough was determined by staining a prepared smear from the semi-finished product with a solution of methylene blue (1:5000). The number of yeast cells was counted after 2 minutes (Magomedov et al., 2010).

Methods for studying the finished products

The acidity of the bread was determined using a method similar to titrating the dough. The moisture content of bread was determined according to the method typical for wheat flour (Skurikhin & Tutelian, 1998).

Statistical processing

All the studies were conducted in triplicate. The results are presented in the form of a mean and standard deviation. A statistical analysis was performed using Microsoft Excel XP and Statistica 8.0. The statistical error of the data did not exceed 5% (95% confidence level).

Results and Discussion

Study of the vegetable raw materials

In the first stage, we studied the organoleptic properties and nutritional value of the vegetable raw materials. The re-

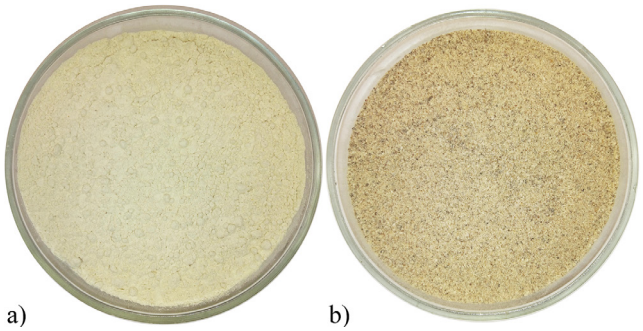

Figure 1. The appearance of the vegetable raw materials *a*) wheat flour, *b*) topinambur powder

sults of testing the consumer characteristics are presented in Figure 1.

It has been established that the topinambur powder differs from wheat flour by its grayish-brown shade and peculiar nutty smell with a slightly sweet taste.

The results of analyzing the chemical composition of the raw materials are presented in Table 2. The studied raw materials did not differ in protein and fat content. The moisture content of the topinambur powder was slightly lower (by 35.3%) than that of wheat flour, which must be taken into account when calculating the amount of water necessary to knead dough.

Table 2. The chemical composition of the vegetable raw materials

Measured indicator	Test results	
	wheat flour	topinambur powder
Mass fraction of moisture, %	13.3 ± 0.3	8.6 ± 0.4
Mass fraction of protein, %	11.9 ± 0.3	11.8 ± 0.3
Mass fraction of fat, %	2.21 ± 0.04	2.22 ± 0.04
Mass fraction of ash, %	0.51 ± 0.03	6.07 ± 0.07
Content of dietary fiber, g/100 g, including:	4.41 ± 0.03	11.13 ± 0.05
– soluble,	1.20 ± 0.02	5.01 ± 0.05
– insoluble	3.21 ± 0.06	6.12 ± 0.08
Content of inulin, %	not found	8.75 ± 0.03
Content of pectin, %	0.22 ± 0.02	9.22 ± 0.10

The chemical composition of the vegetable raw materials

We identified an indisputably high content of dietary fiber in the raw materials from topinambur – it exceeds the content of wheat flour by 2.5 times. At the same time, the level of insoluble fiber in the powder slightly exceeds the soluble fiber (by 22.1%), whereas in the traditional raw materials, on the contrary, insoluble fiber is 2.7 times greater than soluble. The relatively high amounts of soluble fibers in the topinambur powder are consistent with the high pectin content (9.22 ± 0.10%).

Inulin polysaccharide was not found in the wheat flour, but was present at 8.75 ± 0.03% in the topinambur powder.

The high ash content of the vegetable powder (12 times higher in the flour) indicates its rich mineral composition, which was confirmed through further tests (Table 3). The iron content in the topinambur is 5 times higher than in flour, copper – 4.6 times, phosphorus – 3.2 times, magnesium, manganese and zinc – 2–2.5 times, and calcium – 39% higher.

Table 3. The mineral composition of the raw materials

Measured element	Test results, mg/kg	
	wheat flour	topinambur powder
P	948.37 ± 102.05	3078.44 ± 182.15
Ca	2040.63 ± 124.06	2837.40 ± 163.74
Cu	1.81 ± 0.07	8.32 ± 0.83
Fe	19.70 ± 1.65	98.29 ± 7.63
Mg	443.33 ± 37.24	1077.11 ± 100.31
Mn	11.40 ± 1.32	26.76 ± 2.68
Zn	10.10 ± 1.07	21.69 ± 2.09

The mineral composition of the raw materials

It is known that 80% of the protein in wheat flour is composed of prolamins and glutelins (Marks, et al., 2017), while albumins are the main proteins in topinambur (58.2–61.5%) (Krikunova et al., 2016). In this regard, we studied the microstructure of the considered raw materials (Figure 2). We revealed that both of the raw materials contain 3 to 20 μm of protein components with a quantitative dominance of large fractions in the wheat flour, which confirms the differences in the nature and the properties of wheat and topinambur proteins. The structure and size of protein molecules determine the properties of the dough and influence the quality of bread.

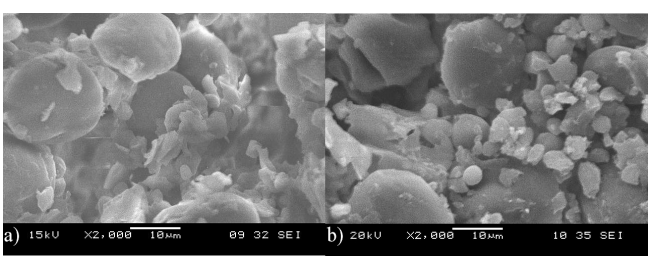

Figure 2. The microstructure of the raw materials (at 2000 times magnification) *a*) wheat flour, *b*) topinambur powder

Study of the semi-finished products

At the second stage of the tests, we studied the influence of different amounts of non-traditional raw materials on the quality of wheat dough. The appearance of semi-finished products is presented in Figure 3.

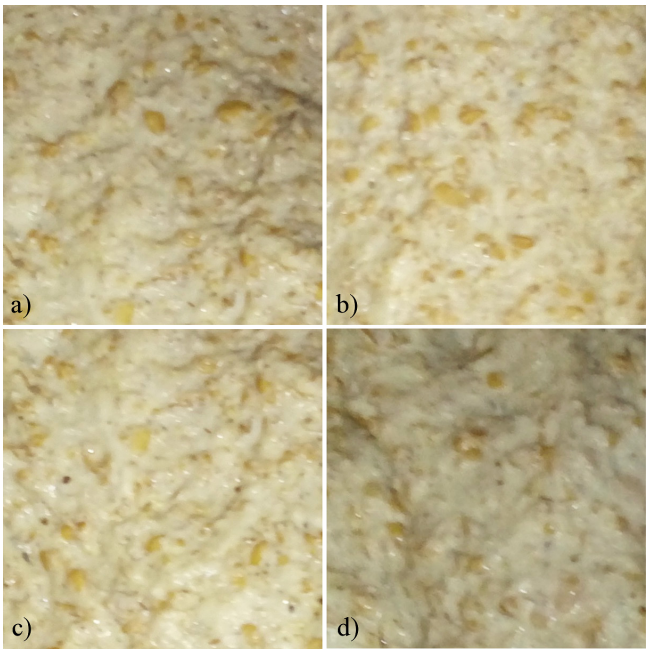

Figure 3. The appearance of the model samples of wheat dough *a*) control, *b*) experiment 1, *c*) experiment 2 *d*) experiment 3

It has been determined replacing wheat flour with topinambur powder in the recipe of wholegrain bread did not negatively affect the organoleptic characteristics of the dough. The model samples of the semi-finished product were thoroughly stirred, loosened masses with the inclusion of straw-yellow granary particles, with a peculiar, slightly sour smell and taste and a convex surface. When the dosage of the non-traditional raw materials was increased to 6%, a subtle grayish tint appeared in the color range of the semi-finished product. However, further physical and chemical tests of the dough allowed us to identify a larger change in the indicators characterizing its fermentation process (Table 4).

We identified an increase in the fermentation activity of the dough when the topinambur powder was introduced. This is manifested both in an increase in the number of yeast cells at the end of dough fermentation, and in an increase in the acidity of the semi-finished product (by 5–6%), with maximum values noted in experiment 3. The activation of the fermentation process in the model samples of wheat dough can be caused by the increase in the semi-finished products' carbohydrate content, including monosaccharides, introduced with the topinambur powder, which are an additional nutrient medium for yeast cells (Zhuravlev & Ladina, 2014; Soboleva & Sharykina, 2016).

Study of the finished products

The final step in our research was to study the consumer properties and nutritional value of the model samples of "Tonus" bread. We did not reveal any changes in the appearance of the products or in the state of the crumb with increased amounts of topinambur powder (Figure 4). The shape of the

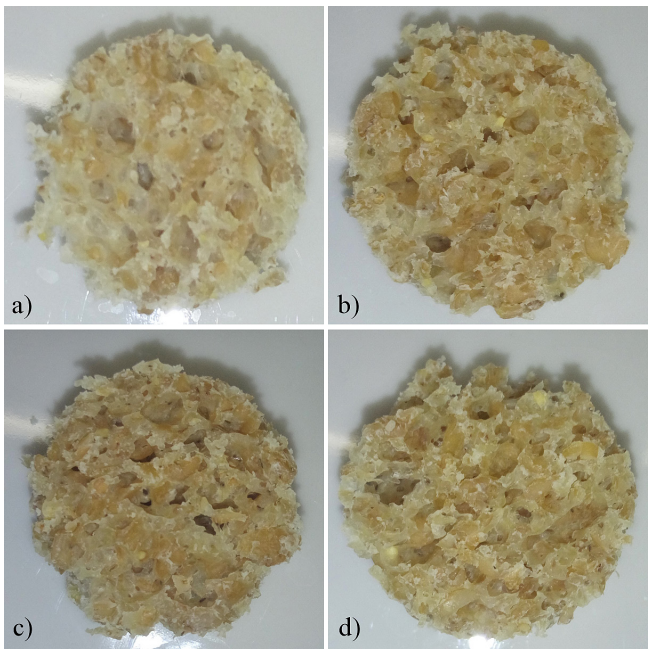

Figure 4. Sectional view of the model samples of wheat bread *a*) control, *b*) experiment 1, *c*) experiment 2 *d*) experiment 3

Table 4. Physical and chemical indicators of wheat dough

Measured indicator	Norm	Test results			
		control	exp. 1	exp. 2	exp. 3
Acidity, degrees	no more than 4.5	4.2 ± 0.2	4.1 ± 0.2	4.2 ± 0.2	4.4 ± 0.2
Number of yeast cells	not regulated	275×10^7	279×10^7	285×10^7	293×10^7

products corresponded to the loaf mould in which the pastry was made, without side spillage. The bread surface was rough; the color of the upper crust was brown and uniform. The crumb was thoroughly baked, not wet by touch, gray, included granary particles of a light brown color, had no traces of undermixing, and had a pleasant typical odor. The porosity was developed, uniform, and thin-walled. The taste of the samples corresponded to typical baked goods, without extraneous, unpleasant flavors.

In further studies, we compared the control and experiment 3, since this experimental sample retained acceptable quality characteristics at the highest topinambur powder amount. We established that the moisture and acidity of the experimental bread samples had a tendency to increase by 4.3 and 5.6%, respectively (Table 5), but did not exceed the regulated requirements (no more than 47% and 4 degrees). The revealed tendency towards an increase in the moisture content of the wholegrain bread containing topinambur raw materials can be explained by the fact that replacing a portion of the flour with topinambur powder leads to an increase in the percentage of the most strongly-bound moisture due to the increased content of pectic substances and inulin. The obtained data are consistent with the research findings presented in a number of scientific papers (Zhuravlev & Ladina, 2014; Soboleva & Sharykina, 2016; Gareeva & Nigmatyanov, 2018).

Replacing wheat flour with topinambur powder did not affect the fat and protein content in the wholegrain bread.

Table 5. The chemical composition of the model samples of wheat bread

Measured indicator	Test results	
	control	exp. 3
Moisture content, %	44.2 ± 0.8	46.1 ± 0.7
Acidity, degrees	3.6 ± 0.2	3.8 ± 0.2
Mass fraction of protein,%	8.9 ± 0.3	9.0 ± 0.3
Mass fraction of fat,%	2.31 ± 0.05	2.33 ± 0.05
Mass fraction of ash,%	1.08 ± 0.02	1.46 ± 0.03
Content of dietary fiber, g/100 g, including:	4.72 ± 0.05	5.34 ± 0.04
– soluble,	1.90 ± 0.02	2.21 ± 0.03
– insoluble	2.82 ± 0.03	3.13 ± 0.04
Content of inulin, %	not found	0.49 ± 0.03
Content of pectin, %	0.23 ± 0.02	0.77 ± 0.04

The total content of dietary fiber in the model bread samples did not have sharp fluctuations but was 13% higher in the experimental samples. Enrichment of wholegrain bread with additional dietary fiber will allow us to eliminate nutritional deficiencies, thereby reducing the risk of the development of colon cancer, irritable bowel syndrome, constipation, gallstone disease, diabetes, obesity, and more. (Baranovsky, 2012; Bokov et al., 2015).

The bread samples enriched with topinambur powder had greater content of pectin (3.3 times more) and inulin than the basic composition samples. The presence of additional pectin and inulin in wheat bread allows us to consider it a dietary and preventive nutrition product. It is known that pectin is very important in the nutrition of healthy individuals in contact with heavy metal salts and radionuclides or living in adverse environmental conditions (Alibayeva & Nogaybayev, 2017; Kuzmina et al., 2018). Inulin is the only natural polysaccharide composed of 95% fructose. Inulin is not absorbed in the stomach; some of it breaks down into short fructose chains and individual fructose molecules in the acidic environment of gastric juice. Inulin has a beneficial effect on individuals from its entrance into the stomach until excretion. The remaining undigested part of inulin is rapidly excreted, binding a large amount of substances which are unnecessary to the body, such as heavy metals, radionuclides, cholesterol crystals, fatty acids, and various toxic chemical compounds. The anti-toxic effect of inulin is enhanced by the action of fiber present in topinambur (Roslyakov, 2014; Shanenko et al., 2016).

Vegetable gelatin (gluten) in wheat bread is formed by proteins – gliadin and glutenin. Gluten plays an important role in bread making and the formation of its porosity (Marx et al., 2017). However, gluten is not found in topinambur. In connection with this, we additionally studied the microstructure of the model bread samples to investigate the influence of the topinambur powder on the formation of their gluten carcass. We discovered that the experimental samples of bread did not differ from the control samples in size, shape, location, and quantity of protein components (Figure 5). Consequently, replacing 6% of wheat flour with the topinambur did not affect the formation of the wholegrain bread texture.

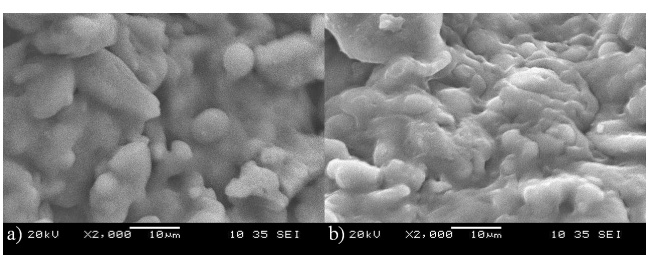

Figure 5. The microstructure of wheat bread (2000 times magnification)
***a*) control, *b*) experiment 3**

Mineralization of the samples of baked goods followed by detection of the elements revealed some differences in favor of the test samples. The bread which had a portion of wheat flour replaced contained more macro- and microelements under study, namely, copper – 16% more, phosphorus – 12%, calcium, magnesium and iron – 10%, zinc – 11%, and manganese – 6% (Table 6). This makes it possible to better satisfy daily nutritional requirements. Mineral substances are very important for maintaining the acid-base balance in the body, building the tissues and bones of the skeleton. Optimizing the mineral supply for the population is the most important factor in maintaining their health and working capacity (Baranovsky, 2012). In this regard, an increase in the mineral value of wheat bread has medico-biological prerequisites and is necessary for eliminating existing micro- and macronutrient imbalances.

Table 6. The mineral composition of the model samples of wheat bread

Measured element	Test results, mg/kg	
	control	exp. 3
P	1565.75 ± 132.43	1758.76 ± 153.22
Ca	1825.42 ± 182.54	2010.84 ± 201.05
Cu	3.03 ± 0.30	3.51 ± 0.29
Fe	67.64 ± 5.87	74.10 ± 6.43
Mg	734.38 ± 54.23	811.86 ± 78.49
Mn	21.82 ± 2.03	23.25 ± 2.12
Zn	13.96 ± 1.16	15.55 ± 1.33

Leveling the significant difference in the quantitative characteristics of mineral elements in the studied vegetable raw materials and finished products seems to be preconditioned by the rich mineral composition of the "Fitness mix" grain mixture which contains micronized wheat grains obtained from whole grains.

Conclusions

Replacing wheat raw materials with topinambur powder in the studied dosage has proved to be efficient in intensifying the fermentation processes of the semi-finished product, increasing the mineral value of grain bread, increasing the content of dietary fiber, namely pectin, and introducing inulin polysaccharide into the products, contrasted with a decreased the gluten load on the human body.

Acknowledgements

The research was carried out with the support of the Government of the Russian Federation (Decree № 211 of 16.03.2013), agreement № 02.A03.21.0011.

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Received: August, 16, 2019; *Accepted:* September, 10, 2019; *Published:* June, 30, 2020