Technology of gluten-free pastries using sorghum flour

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Abstract. The purpose of this research is to create a new way of making gluten-free foods. Gluten-free cereals acreages in Russia were analyzed. It was revealed that gluten-free cereals have much less acreages than wheat one which is why gluten-free food production in Russia is so poorly developed. It is suggested to use sorghum flour as gluten-free non-traditional raw material. Physical-chemical properties of sorghum flour were determined. Gluten-free biscuit, custard and chocolate cream were obtained. Determination of obtained products organoleptic properties was conducted by potential gluten intolerant customers.

1. Introduction
Grain and flour are the foundation of Russian population nutrition. Wheat and rye are the most common cereals. Both of them contain prolamin proteins. Wheat protein called gliadin. Rye protein called secalin [1]. Gliadin and secalin are part of protein group called gluten. That is why wheat and rye cereals containing gluten.

Nowadays gluten intolerance is a subject of current interest. The diagnosis of celiac disease has been developed in the mid-sixties of the twentieth century [2]. Ever since gluten intolerant people could be convinced that they had this disease and they should stick to gluten-free diet.

Unfortunately, the diagnosis of celiac disease in Russia is still difficult. That is why many people don’t know about having gluten intolerance. They ignore symptoms such as diarrhea, constipation, bloating, abdominal pain, fatigue, nausea, headaches and skin rash.

Market of gluten-free food in Russia was analyzed. It was revealed that range of gluten-free bread is wider than range of gluten-free pastries. So purpose of this research is to create new ways of making gluten-free pastries using non-traditional raw material.

2. Literature review
Gluten intolerance can come out as food allergy or as autoimmune disease.

Gluten food allergy is an allergic reaction to a specific protein. Blood of person who has gluten food allergy contains antibodies IgE. This fact is common to any allergy.

Celiac is autoimmune disease. It induces inflammation of small intestine during gluten digestion. T- and B-cell immune responses are activated as an answer to gluten arrival which leads to the fact that the mucosa of the small intestine is inflamed. Villi of the small intestine are affected. Nutrient absorption processes are disturbed. As a result, antibodies IgA and IgG are produced [3].

In both cases gluten-free diet is often only and the most effective cure. So working-out of gluten-free pastries technology is topical issue and it requires consideration.
Celiac is partly genetic disease. It means that heredity may increase the risk that person would have gluten intolerance. But heredity is not the only factor which influences on risk of having disease. We can assume that number of gluten intolerant people will be increasing every year. According to statistics, in the USA one in every 133 people have celiac disease, which means approximately 2.4 million people have the condition [4]. However, more than 2 million of these haven't yet been diagnosed. There are from 3 to 6 million gluten intolerant people in Russia.

Scientific studies of making pastries and sweet fillings in Russia were analyzed. Most of the researches are related to making new types of antioxidants and emulsifiers or to creation new ways of production quality control. There are some studies related to making diabetic foods using non-traditional raw materials. There are also researches of creation new pastry recipes containing vegetables and fruits.

There is insufficient number of gluten-free production researches in Russia. One of this type studies was published in Kemerovo State Agriculture Institute. Recipe of gluten-free bread containing rice flour, corn starch and carob was designed. It is pointed out that that by using carob we can make porous bread with elastic crumb [5].

Scientists of Bashkir State Agrarian University designed cake recipe using amaranth flour. This recipe contains only 4 % of amaranth flour and 96 % of wheat flour [6]. New kind of cake recipe was designed. But in fact this cake can’t be classified as gluten-free product because it contains wheat flour.

Scientists of Moscow State University of Technology and Management published several studies related to gluten-free foods production. They suggest making gluten-free biscuit using corn flour and corn starch. Properties of gluten-free biscuit were determined [7]. Gluten-free custard gingerbread recipe was also designed. The peculiarity of this recipe is that gluten-free flour partially replaced by potato starch [8]. MSUTM scientists used different types of gluten-free raw materials such as rice, amaranth, buckwheat, sesame, flax, pumpkin flour [9].

Following an analysis of the current scientific studies in Russia, it can be concluded that production of gluten-free foods in Russia is poorly developed. Therefore, gluten-free foods production in Russia has barely started.

3. Methodology
Gluten-free pastries production research involves several stages.

3.1. Analysis of gluten-free products market in Russia
The task of this research was to reveal level of market development. Marketing analysis was conducted as survey by using Internet. 160 gluten-intolerant respondents were interviewed.

3.2. Gluten-free cereals acreages analysis
It was conducted with the help of Russian Federal State Statistics Service data. It revealed information about corn, rice, buckwheat, soybean, sorghum and wheat acreages.

3.3. Physical-chemical properties determination of wheat flour and sorghum flour
They were established according to the Russian technical standards GOSTs.
Moisture content was examined using thermogravimetric method. The temperature was 130 °С. Chemical drying cabinet AKROS 4610 was used.

Ash content was examined using thermogravimetric method without any chemical process accelerator. The temperature was 850 °С. Muffle furnace PM-10 was used.

Acidity of flour was using titrimetric method. Concentration of NaOH solution was 0.1 mol/dm3. Phenolphthalein was used as indicator.

Wet gluten content was determined. We used dough mixed from 30 g of flour and 19 ml of water and gluten measuring device IDK-3M.
3.4. Recipes selection and gluten-free pastries baking

The most common recipes of biscuit, custard and chocolate cream were used. The source of these recipes is culinary collection [10].

Biscuit contains 160 g of sorghum flour, 200 g of sugar and 150 g of egg mélange. The dough was mixed by hands. Bakeware sets were filled. Baking options was 220 °C and 20 min.

Chocolate cream contains 100 g of sorghum flour, 330 g of condensed milk, 330 g of butter, 660 g of powdered sugar, 82.5 g of cocoa powder. Flour, butter, powdered sugar and cocoa powder were mixed by hands. Cream mass was cooked for 5 min. Then condensed milk was added and cream cooked for another 10 min at a temperature 70 °C.

Custard contains 100 g of sorghum flour, 100 g of butter, 360 g of sugar, 1000 ml of milk, 560 g of egg mélange, 2 g of vanillin flavoring. The sorghum flour was browned. Mélange and sugar were grounded by hands. Then flour and milk at a temperature 10 °C were added. Cream mass was cooked at 60 °C for 5 min. Then butter was added and cream was coked for another 5 min.

Gluten-free pastries were made by using laboratory oven SHL-065 SPU. Wheat-containing biscuit, custard and chocolate cream were made as control samples.

3.5. Determination of obtained gluten-free products organoleptic properties

Organoleptic properties were determined by potential customers. 15 respondents who have gluten intolerance were found in Samara Oblast. Two gluten-free biscuits were presented for analysis. One of them was covered with chocolate gluten-free cream, the other one was covered with gluten-free custard. Gluten-free products were rated on a five-point scale by five quality indicators which are color, aroma, taste, texture, homogeneity.

3.6. Determination of obtained gluten-free products physical-chemical properties

They were established according to the Russian technical standards GOSTs. Determined properties of gluten-free sweet fillings were contents of moisture, fat and total sugar. Moisture content was determined using thermogravimetric method. The temperature was 130 °C. Chemical drying cabinet AKROS 4610 was used. Fat content was determined using method of extraction and weighing. Chloroform was used as a fat solvent. Total sugar content was determined using the ferricyanide method.

Determined properties of gluten-free biscuit were alkalinity and contents of moisture, ash, fat, total sugar. Moisture content was determined using thermogravimetric method. The temperature at chemical drying cabinet AKROS 4610 was 130 °C. Ash content was determined using thermogravimetric method. The temperature at muffle furnace PM-10 was 600 °C. Fat content was determined using method of extraction and weighing. Alkalinity was determined using titrimetric method. The main chemical reagent was 0,1 mol/dm3 sulfuric acid. Bromothymol blue was used as indicator. Total sugar content was determined using the ferricyanide method. The main equipment of this analysis was colorimeter KFK-3.

4. Results

Research of making gluten-free pastries was carried out in Food Production Technologies Department of Samara State Technical University. First of all, we interviewed some people who have gluten intolerance. Purpose of this research was to outline level of gluten-free market development in Russia. There were fifteen survey questions. Marketing analysis is a subject of separate study so here we present received answers for only two questions.

It was revealed that more than 80 % of respondents aren’t satisfied with range of gluten-free products. Diagram of received response is presented on figure 1. We can conclude that production of gluten-free products in Russia is poorly developed. People who live in border town notice that range of this products in Finland and Estonia is comprehensive.

Respondents noted that production bought by them is based on different types of gluten-free raw materials. Diagram of received answers is presented on figure 2.
Based on the responses received, it can be established that gluten-free products sold in Russia consists of various gluten-free flours. Corn, rice and buckwheat are valuable cereals in Russia market. They are used to make porridges. So conversion of these cereals is unprofitable process. Acreages of corn, rice, buckwheat, soybean, sorghum are presented in table 1. Wheat cereal is the most common in Russia so it’s acreage is presented for comparison.

**Table 1.** Acreages of gluten-free cereals in Russia in 2017.

| Cereal   | Acreage, thousand hectares | Percentage by 2016 | Percentage of all Russian Federation crops |
|----------|-----------------------------|--------------------|------------------------------------------|
| Wheat    | 27890,7                     | 513,9              | 100,6                                    |
| Corn     | 3026,7                      | 38,9               | 104,5                                    |
| Rice     | 186,7                       | —                  | 89,9                                     |
| Buckwheat| 1691,4                      | 29,6               | 140,5                                    |
| Soy      | 2635,4                      | 23,1               | 118,3                                    |
| Sorghum  | 140,7                       | 7,9                | 61,5                                     |

There is no information about acreages of almond, coconut, amaranth and tapioca in Russia. It can be explained by Russian climatic features. These cereals are grown in tropical countries.

By comparing wheat acreage with acreages of gluten-free cereals it can be concluded that production of the last ones is very small. Among all gluten-free cereals, rice has the largest percentage of all Russian Federation crops. Rice, buckwheat and soy are used as croups. Corn is used in making preservation and corn starch. Therefore, there is almost no production of gluten-free flour from these cereals. This production is economically unprofitable. That is why gluten-free foods production in Russia is in its current level of development.

While comparing sorghum acreage we see that it is small and similar to rice acreage. Nowadays sorghum is used to make paper and feed for farm animals. By increasing acreage of sorghum cereal we can create production of sorghum flour and then use it to make gluten-free foods. Sorghum acreages over the last eight years are presented on figure 3. It shows that sorghum acreage was at maximum in 2016. Acreage of sorghum needs to be increased to provide sustainable development of food industry in Russia. That is the way we can organize the production of gluten-free flour and pastries based on it.
Table 2. Determination of physical-chemical properties of flour.

| Property              | Sorghum flour | Wheat flour |
|-----------------------|---------------|-------------|
| Moisture content, %   | 13,9          | 11,5        |
| Ash content, %        | 0,54          | 0,53        |
| Acidity of flour, deg.| 6,4           | 2,8         |
| Wet gluten content, % | 0             | 27          |

Gluten-free biscuit, chocolate and custard were made according to the previously described recipes. Obtained products are presented on figure 4 and figure 5.

Figure 4. Custard and chocolate cream based on sorghum flour.

Figure 5. Gluten-free biscuits.

Potential customers rated organoleptic properties of these products. Respondents who suffer from gluten intolerance got two gluten-free products which were biscuit covered with chocolate cream and biscuit covered with custard. Diagram presented on figure 6 was constructed using obtained assessment.
Figure 6. Organoleptic properties of obtained products on a five-point scale.

Results of sweet fillings physical-chemical analysis are presented in table 3. Samples containing gluten was made as a comparison. These samples were called control and its properties are in third and fifth columns. Obtained results show that replacing wheat flour with sorghum one has no effect to contents of moisture fat and total sugar. Gluten is a protein so we can suggest that this replacement effects only protein composition of products.

Table 3. Physical-chemical properties of gluten-free sweet fillings.

| Property                  | Gluten-free chocolate cream | Chocolate cream (control sample) | Gluften-free custard | Custard (control sample) |
|---------------------------|-----------------------------|---------------------------------|----------------------|--------------------------|
| Moisture content, %       | 6,9                         | 6,5                             | 64,4                 | 59,4                     |
| Fat content, %            | 18,1                        | 20,8                            | 7,8                  | 8,1                      |
| Total sugar content, %    | 61,8                        | 61,3                            | 23,0                 | 22,6                     |

Results of biscuit physical-chemical analysis are presented in table 4. Biscuit sample containing gluten was made as a comparison. This sample was called control and its properties are in third column. Inclusion of sorghum flour in biscuit recipe has effect on total sugar content which slightly increases. The rest of the properties stay within similar limits. It allows us to conclude that by replacing wheat flour with sorghum one in pastry recipes we can make high quality products. Its quality properties remain at a consistently high level.

Table 4. Physical-chemical properties of gluten-free biscuit.

| Property                  | Gluten-free sample | Control sample |
|---------------------------|--------------------|----------------|
| Moisture content, %       | 18,3               | 17             |
| Ash content, %            | 0                  | 0              |
| Fat content, %            | 4,5                | 4,5            |
| Alkalinity, deg.          | 0,5                | 0,5            |
| Total sugar content, %    | 60                 | 57,3           |

5. Discussion

All of obtained products were highly rated by potential customers. They noted pleasant aroma and sweet taste. Nevertheless, they also noted presence of brown spots and cracks on biscuit surface which are visible on figure 4. Further research is needed. We should combine sorghum flour with other gluten-free raw materials so that we can make high quality gluten-free foods.

In can be concluded that it’s necessary to continue research of gluten-free production. We need to expand raw material base, to organize production of gluten-free flour and gluten-free foods. This is the
only way which allows us to meet the needs of specific population group and helps gluten intolerant people to easily diet throughout life.

6. Conclusions
In accordance with the work carried out it can be concluded that using sorghum flour while making gluten-free pastries and fillings is a perspective way of food production development. At the present time production of gluten-free foods in Russia is poorly developed. By using sorghum cereals we can organize the production of gluten-free breads and pastries. So that we can provide gluten intolerant people with essential food.

There are several advantages in conversion of sorghum cereals. This culture is thermophilic and is already growing in some Russian regions. By increasing acreage of sorghum cereal we can organize production of sorghum flour. This type of flour is well suited for replacing wheat flour and creation new gluten-free recipes. This replacement does not require complex technological operations and allows reducing the period of production adaptation.

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