Development of a recipe for sugar cookies with a reduced glycemic index

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Abstract. The disadvantage of confectionary lies in its unbalanced composition and high glycemic index. It has a high energy value because of the high content of refined ingredients such as fat, sugar and flour. However, the physiological value, biological value and biological efficiency are quite low. Excessive consumption of confectionery can lead to metabolic disorders in the organism and many endocrine diseases, such as diabetes mellitus and obesity, as well as atherosclerosis, cardiovascular diseases and others. It is, therefore, necessary to create new products containing carbohydrates with a low glycemic index or to adjust existing recipes in order to reduce refined sugars in them, as well as to improve the nutritional value in general. In this paper, we present the information on the creation of confectionery with a practical orientation. Based on an analytical evaluation of the nutrient composition of sugar cookies and properties of some sugar substitutes of natural origin, we developed a cookie recipe with complete replacement of sugar by a mixture of fructose and stevioside. We carried out an organoleptic evaluation of innovative products containing sugar substitutes in different proportions. Based on blood glucose level measurement, there were calculated the glycemic index and glycemic load of the developed cookies. It was found that the glycemic index was reduced by 26% in comparison with confectionery made according to traditional recipes. There were also noted high organoleptic indices of developed cookies. The obtained result allows recommending it for prevention of development of such diseases like obesity and diabetes mellitus, as well as to include in the diet of different population groups.

1. Introduction
Today, the problem of balanced nutrition is one of the most important social problems [1]. Everybody needs to get a certain amount of energy daily with food, as well as various macro and microelements, vitamins, essential amino acids and fatty acids. The decrease in living standards of the population connected with economic and social difficulties, as well as the development of technical progress, led to changes in the way of life of modern humans. The decrease in energy expenditure and physical activity, stress, bad habits, as well as an increase in consumption of products containing easily assimilated carbohydrates, subjected to various technological treatments, harmed the general state of human beings.

In modern society, the problem of balanced nutrition is the most pressing and requires the development of new technologies, one of which is the introduction of products in the human diet that contain components correcting the nutritional status of a person. They contribute to the increase of
protein content, essential amino acids, polyunsaturated fatty acids, reduction of the glycemic index (GI) of refined food products. No food product contains all food substances in optimal quantities and the right proportions. That is why healthy nutrition is only possible with food that provides balanced diets for all necessary nutrients. These include products of functional purpose [2-4].

The purpose of the research is to develop a sugar cookie recipe with a reduced glycemic index. In order to achieve the set goal, there were justified the choice of sugar substitutes, carried out the preliminary correction of confectionery products composition and performed control studies to optimize the recipe composition, evaluated the quality indicators of developed products and calculated GI and GN of obtained products.

2. Materials and methods

The main recipe components used for the cookie control sample were wheat flour, sugar, butter, milk and eggs.

The calculation of the sweet equivalent replacement of sugar by its substitutes was calculated by the formula (1):

\[ S_a = \frac{m_s}{k} \]

where \( S_a \) is the required amount of the sweetening agent, kg; \( m_s \) is the amount of sugar to be replaced, kg; \( k \) is the approximate factor of the sweetness of the sweetening agent.

Evaluation of organoleptic indicators was carried out with the help of non-professional tasters on a five-point scale by simultaneous presentation of coded samples of functional products and a control sample. The results were used for creating profiles with descriptors: colour, aroma, taste, consistency, appearance.

For calculating the GI, the blood glucose level was measured in a group of volunteers of 50 people aged from 20 to 25 years. For this purpose, there was used a glucometer (Accu-Chek Active, Germany). The measurements were done in the morning "on an empty stomach" and after the use of functional confectionery until the complete recovery of blood sugar levels. The glycemic index was calculated as the relation between the areas under the graph obtained from blood glucose measurements after consumption of the product and after consumption of glucose solution.

Glycemic load was calculated using formula (2).

\[ GL_l = \frac{G_l \cdot m_c}{100} \]

where \( G_l \) is a glycemic index, unit; \( m_c \) is a carbohydrate mass in 100g of product.

Humidity was determined by the gravimetric method, alkalinity by the titrimetric method using standard techniques.

3. Results

One of the options to reduce the GI of products is the use of sugar substitutes. The following indicators relative to sucrose were taken into account when choosing them: the degree of sweetness; energy value; hygroscopicity, carcinogenicity, glycemic index, insulin index [5-7].

The analysis of natural sugar substitutes presented in Table 1 shows that they do not have cariogenicity, unlike sucrose. Sorbitol, isomalt, lactate are characterized by the higher or comparable caloric content of sucrose, while the degree of their sweetness is much higher than that of sucrose. These sweetening agents have low glycemic and insulin indices. Mannite also has a low index, and stevioside has a zero index. However, each of the considered sugar substitutes has both advantages and disadvantages. For example, the use of fructose if the recommended daily doses are exceeded in the diet may lead to liver obesity. Stevioside has a specific intense aftertaste, which is characterized as unpleasant. Mannite gives a cool feeling in the mouth and is almost insoluble in foods that contain...
much fat. The optimal solution is to combine several sugar substitutes in a particular proportion. This process will reduce the undesirable effect of the individual substance. In this paper, we chose fructose and stevioside as sugar substitutes.

Fructose is the sweetest of natural sugars; it is 1.7 times sweeter than crystal sucrose. This fact makes it a promising sweetener which provides the same sweetness as sucrose but has a lower nutritional value. Fructose affects blood glucose levels to a much lesser extent, so it is acceptable for people with diabetes to consume in moderate amounts.

Table 1. Properties of some sugar substitutes

| Sugar Substitutes | Properties |  
|-------------------|------------|
|                   | Degree of sweetness, relative to sucrose (1) | Energy value, Kcal/g | Hygroscopic property | Cariogenicity | Glycemic index, g GGE/100 g |
|---|---|---|---|---|---|
| Sucrose | 1.0 | 4.0 | low | yes | 68 |
| Stevioside | 300 | - | high | no | - |
| Fructose | 1.7 | 3.6 | high | no | 19 |
| Sorbitol | 0.6 | 3.2 | high | no | 9 |
| Isomalt | 0.45-0.65 | 2.4 | low | no | 9 |
| Lactite | 0.4 | 2.4 | low | No | 5 |
| Mannite | 0.5 | 3.7 | low | no | - |

Stevioside is a natural, intense sweetener. It is characterized by a high degree of sweetness; it is not caloric; does not increase blood pressure; has no special contraindications. During the optimization of its proportion, we were guided by the resulting technological effect and organoleptic characteristics of the products. Table 2 shows the fructose and stevioside proportion (with complete sugar replacement), based on which we developed the cookie recipe.

Table 2. Proportion of sugar substitutes

| Experiment, № | Fructose, % | Stevioside, % |
|---------------|-------------|---------------|
| 1             | 100         | 0             |
| 2             | 80          | 20            |
| 3             | 60          | 40            |
| 4             | 40          | 60            |
| 5             | 20          | 80            |
| 6             | 0           | 100           |

It is estimated that if sugar was completely replaced by stevioside, the products were poorly moulded as this sweetener does not bind or retain moisture contained in the dough. The cookies had an unpleasant bitter aftertaste. Samples containing only fructose were characterized by high humidity, as this sweetener has a strong hygroscopic effect. The best compromise is to replace 80% of sugar with fructose, 20% with stevioside. The results of organoleptic research are presented in Figure 1. Indicators for the control sample were taken equal to 5 points for all descriptors.
At the next stage, we investigated the main physicochemical parameters of samples № 2 and 3, which received the highest organoleptic evaluation.

When determining the moisture of the cookies, the measurements were made immediately after ageing and during storage for seven days. Further storage is considered to be inappropriate since this product is recommended for use in public catering facilities and is served to the consumer immediately after the production. The results are shown in Figure 2.

It was found that the moisture of the test samples increases with the concentration of fructose. This result is because fructose is highly hygroscopic and absorbs water vapour from the air. Since the moisture content of the cookies increases with the increase in fructose added to the recipe, it is necessary to study their alkalinity, including during storage (Fig 3).

The use of an intensive sweetening agent in the cookie recipe resulted in a slight decrease in the production of finished products with high consumer properties. According to the results of the organoleptic and physicochemical parameter for further research there was chosen a pilot sample of cookies, the recipe of which is presented in Table 3.

Then there was calculated a glycemic index, which indicates the ability of the product to trigger insulin production. The results of blood glucose measurement of volunteers when they consume reference, test samples and glucose solution needed to calculate the glycemic index are shown in Figure 4.
Figure 3. Change in alkalinity of reference and test samples.

Table 3. Test sample cookie recipe №3

| Ingredient                  | Gross weight, g |
|-----------------------------|-----------------|
| Eggs                        | 1 piece         |
| Creamy butter 72.5%         | 135             |
| Fructose                    | 139             |
| Stevioside                  | 0.24            |
| Premium wheat flour         | 594             |
| Milk 2.5%                   | 100             |
| Vanillin                    | 3               |
| Baking soda                 | 8               |
| Product yield               |                 |

Figure 4. Changes in blood glucose levels when using reference and test cookie samples compared to pure glucose.

It was found that the glycemic index of control and prototype samples is 88 and 58 units. Thus, adding fructose and stevioside to the cookie recipe instead of 80% and 20% sugar, respectively, allows reducing the glycemic index by 26%.
Simultaneously with the calculation of the GI, it is necessary to calculate the glycemic load of carbohydrates in the product. This parameter takes into account not only their source but also their quantity. The glycemic load of the reference and test samples was calculated using formula 2. It was 34 and 50 units. In general, the use of sugar substitutes can reduce GL by 32%.

4. Conclusion
As a result of research there was chosen the optimal ratio of fructose and stevioside in sugar cookies with its complete replacement. There was corrected the recipe composition of the innovative product, the quality indicators of finished products responsible for consumer appeal were evaluated. It was found that indicators of glycemic index and glycemic load of the developed product decreased in comparison with the reference sample. The resulting sugar cookies are recommended for inclusion in diets of different population groups, including people at risk of obesity and type 2 diabetes mellitus.

References
[1] Kanarskaya Z, Khuzin F, Ivleva A and Gematdinova V 2016 Trends in the development of confectionery technology Bulletin of Voronezh State University of Engineering Technologies 3 195–204
[2] Popova N, Shchetilina I, Denisova A and Kiseleva E 2016 Development of low glycemic index wafers Bulletin of Voronezh State University of Engineering Technologies 2 181–186
[3] Popova N, Shchetilina I and Denisova A 2018 Study of the glycemic index of cottage cheese based culinary products with natural sugar substitutes application Materials 18 International multidisciplinary scientific Geoconference SGEM pp 645–561
[4] Nikitin I, Bogatyrev V, Mironchenko Ya and Lavrov S 2017 Development of chocolate technology for dietary purposes based on natural sweeteners Bulletin of Voronezh State University of Engineering Technologies 2 153–158
[5] Mitchell H 2010 Sweeteners and sugar replaces edited (St. Petersburg: Professiya Publishers).
[6] Livesey G 2003 Health potential of polyols as sugar replaces, with emphasis on low glycaemic properties Nutrition Research Reviews Eng. 16 163–191
[7] Foster-Powell K 2002 International table of glycemic index and glycaemic load values Amer. J. of Clinical Nutrition Eng. 76 5–56

Figure 5. Change of areas under glycemic reaction curves.