Modeling Formulations of Food with Prophylactic Antidiabetic Properties

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Abstract. Having analyzed the research literature, the authors identify biologically active compounds with antidiabetic properties. It has been established that brewer’s yeast, selenium active, chromium chelate and lecithin have a positive effect on reducing blood sugar. A technology for obtaining a modified yeast preparation by destroying cell walls has been proposed. A biologically active composition for the prevention of diabetes mellitus has been developed and used as an additive in the recipe for the diabetic boiled sausage. Laboratory animals were used to assess the prophylactic properties, biological value and safety of a sausage with a biologically active composition; as a result, the effectiveness of the developed technology was confirmed.

1. Introduction
Long-term research in the field of nutrition has shown the effectiveness of correctly selected components of food products for the prevention of various human diseases. The analysis of research literature made it possible to identify the sources of biologically active ingredients that could positively influence metabolic processes in patients with diabetes mellitus. Lecithin belongs to the esters of the amino alcohol choline. There is evidence of the effect of lecithin on blood glucose. Probably, lecithin activates the insulin receptor and has a beneficial effect on the rate of penetration of glucose through the cell membrane. Lecithin is the basic for the formation of the intercellular space and a part of the cell membrane. Being a building material, it is involved in the renewal of damaged cells. Data on the intermolecular interaction of lecithin and the insulin receptor are not yet available. However, the benefits of the use of lecithin in the diet by people suffering from diabetes have been proven [1, 2, 3, 4].

One of the effective additional methods in the treatment of diabetes mellitus is the use of brewer’s yeast in nutrition. Yeast biomass contains 50% protein on dry matter, the rest consists of B vitamins - B1, B2, PP, B6 pantothenic acid, D; extractive and mineral substances, including trace elements and other chemical compounds necessary for nutrition. Brewer’s yeast is widely used in medical institutions for the treatment of diabetes mellitus. Consider the fact that in the brewing industry at the end of the beer production cycle, residual brewer’s yeast appears; some amount is used as seed material, whereas the rest is waste; therefore, the use of unclaimed yeast biomass is of interest from the point of view of processing secondary raw materials of brewing [5, 6, 7, 8].
It is known that in order for insulin to maintain normal blood glucose levels, it needs chromium. In the pharmaceutical industry, a preparation called chromium chelate is produced, which could have a positive effect on the regulation of blood glucose [9, 10, 11].

The trace mineral selenium is known to have effective antioxidant properties. The use of selenium in the diet can reduce blood sugar levels and, as a consequence, reduce the dose of insulin for type 1 diabetics. The pharmaceutical industry produces the drug selenium active, which is recommended for diabetics [8, 9].

2. Formulation of the problem

Diabetes mellitus is a global problem for the world’s population. In 2020, 5.1 million cases of diabetes mellitus among adults and 50 thousand among children were registered in Russia. There is a wide range of medications used to treat diabetes mellitus, including metformin, glycomet, glycone, and many others. It should be borne in mind that often the use of drugs by diabetics leads to gastrointestinal upset, high blood pressure, kidney stones, cancer and many other diseases. The increased content of insulin in the blood contributes to the destruction of cell membranes, disrupts the energy balance, and accelerates the aging of the body. Therefore, it is very important to develop functional foods with prophylactic properties.

Brewer’s yeast (Saccharomycetales) has a fairly strong cell membrane, the outer layer of which consists of fiber, and the inner part of the protoplasm cell is mainly protein. There is a problem of extracting useful substances (vitamins, minerals, etc.) outside the cell membrane of yeast and ensuring the possibility of their assimilation by the human body.

The research aim was to develop a technology for a biologically active food additive, and its use in food formulations for the prophylaxis of diabetes mellitus.

3. Materials and methods

During the research, brewer’s yeast (GOST R 53358-2009 Brewing Products); lecithin (GOST 32052-2013 Food additives Lecithins E322); lysozyme (GOST 32052-2013 Food additives lysozyme E1105); chromium chelate (Nature’s Sunshine Products Inc.); selenium active (Manufacturer: Moscow Eco-Food Plant Diode); raw meat materials for the production of sausages in accordance with GOST 9792-73 (Sausages and products from pork, lamb, beef and meat of other types of slaughter animals and poultry) were used.

The release of nutrients from yeast biomass was carried out with a laboratory high-speed homogenizer ESPREAD. The chemical composition of the finished products was determined with a FOSS FoodScan 2 Meat analyzer; a modular KNAUER amino acid analyzer was used to determine the amino acid composition of the products. The mineral composition of sausages was studied using a Spectroscan Max GV universal analyzer. The vitamin composition of the product was determined with an LCMS-10EV liquid chromatograph.

The biological value of the composition was assessed using white mice (BALB/C line) with 20–30 g weight. Blood biochemical parameters were determined using a Cobas c 111 analyzer (Roche Diagnostics) [12, 13, 14, 15].

The optimization of the recipe composition was carried out in blocks of multidimensional scaling, cluster analysis of the Statistic v. 10, 12 applications; the creation and processing of multidimensional data sets were carried out in the Statistic Neural Networks module. To exclude errors and misses, the data analysis was performed in 3 – 5 repetitions using the Error per Case module (significance level p ≤ 0.05).

4. Results and discussion

Based on the analysis of the diabetics’ nutrition structure, a deficiency in the diet of vitamins B1 and PP was revealed, and the expediency of using yeast biomass, lecithin, chromium chelate and selenium active in the diet was established. The destruction of the cell wall was carried out by treating the yeast biomass with lysozyme at the optimal values of active acidity and temperature for the applied enzyme
preparation, followed by the destruction of the cell walls on a high-speed homogenizer. The establishment of optimal modes was carried out by implementing the planning matrix, by analyzing the degree of destruction of cell membranes, creating an array, visualizing the results by the method of multidimensional scaling (figure 1) and optimizing the process.

![Figure 1. Results of optimizing homogenization parameters](image)

Figure 1. Results of optimizing homogenization parameters
a) contour surface; b) 3D – surface.

The optimization of the process of fermented yeast biomass homogenization was carried out according to a two-level plan of experiment with such factors as the duration of treatment, the speed of rotation of the homogenizer, and the temperature of the process. As a result, with optimal parameters, it was possible to destroy cell walls almost completely. Microscopic photographs of the original biomass and the biomass after processing are shown in figure 2.

![Figure 2. Optimization of the process of extracting nutrients from yeast biomass](image)

Figure 2. Optimization of the process of extracting nutrients from yeast biomass
a) the original yeast biomass; b) biomass after homogenization.

In figure 2, no intact yeast cells are observed. The resulting homogenized biomass was dried at a temperature of 50–60° C to a moisture content of 8% in the final product. Lecithin, chromium chelate and selenium active were added to the dry yeast product (taking into account the consumption rates), the content of deficient vitamins (B1, PP) and the mineral composition were determined. The content of vitamin B1 was 0.2, PP - 0.4 mg%. The biologically active food composition is presented in table 1.
Table 1. The content of biologically active food composition.

| Composition components   | Content, % |
|--------------------------|------------|
| Modified dry yeast biomass | 60         |
| Selenium active          | 0.05       |
| Chromium chelate         | 0.05       |
| Lecithin                 | 39.9       |

The mineral content of biologically active composition was studied (table 2).

Table 2. The mineral content of biologically active composition.

| Element | Maximum allowable concentration, mg/kg | Content in the composition, mg/ |
|---------|----------------------------------------|-------------------------------|
| Lead    | 0.05                                   | Not found                     |
| Arsenic | 0.50                                   | -<-                           |
| Cadmium | 0.05                                   | -<-                           |
| Mercury | 0.03                                   | -<-                           |
| Copper  | 5.00                                   | 10.09                         |
| Zinc    | 40.00                                  | 0.92                          |
| Calcium | -                                      | 4953.60                       |
| Selenium| -                                      | 0.0009                        |
| Iron    | -                                      | 106.40                        |
| Chromium| 0.20                                   | 0.08                          |
| Sodium  | -                                      | 683.80                        |
| Potassium| -                                      | 9328.50                       |

The research resulted in a technological scheme of a biologically active composition and a draft of normative and technical documentation. The resulting composition was included in the recipe for boiled sausage “Diabeticheskaya” based on 5 kg per 100 kg of the main raw material. The prototype contained magnesium - 19.5; phosphorus - 160.0; potassium - 260.0 mg per 100 g of the finished product. The use of 200 g of the product per day completely eliminates the lack of chromium, zinc, vitamins PP and B1, selenium in the diet. The content of the essential elements under study did not exceed the permissible limits. Microbiological indicators were in accordance with the requirements of SanPiN 2.3.2. 1078 - 01.

The assessment of the biological value and safety of boiled sausage with a biologically active composition was carried out on laboratory animals, studying the growth-weight (Fig. 3) and hematological characteristics of the blood of test specimen. The studies were carried out on three groups of animals (5 animals in each: group 1 (control 1) - the main diet; 2, 3 groups - animals with alloxan diabetes (group 2 (control 2) - sausage “Diabeticheskaya” and the main diet; group 3 (experiment) - the main diet and sausage “Diabeticheskaya” with a biologically active composition).
Figure 3. Analysis of the growth and weight characteristics of experimental animals for the study period.

The number of days and the magnitude of the drop in live weight in experimental animals of groups 2 and 3 were less than in group 1, which received the main diet of the vivarium. Analysis of the process of changing the live weight of experimental specimen during the experiment indicates that the use of sausages in the diet does not have a negative effect on the physiological state of the experimental animals.

Feeding with sausage with the developed composition increased the content of leukocytes in the 2 and experiment groups (by 5.4% and 5.2%) compared to intact animals. There was an increase in protein on the 40th day of the experiment in group 3 by 8.05% and immunoglobulin by 7.7%.

The change in blood glucose is presented in Table 3. This figure was much lower than in the 2nd experimental group that received meat products without a biologically active composition.

Table 3. Changes in the blood glucose content of experimental animals.

| Groups of experimental animals | Research period, days |            |            |            |
|-------------------------------|----------------------|------------|------------|------------|
|                               |                      | 7          | 14         | 28         |
| Glucose content, mmol/l       |                      |            |            |            |
| Control 1                     | 4.38±0.42            | 4.30±0.28  | 4.23±0.32  |
| Control 2                     | 8.45 ± 0.22          | 18.17±0.33 | 15.21±1.85 |
| Experiment                    | 8.75±0.44            | 11.95±0.47 | 6.95±0.39  |

The serum activity of blood marker enzymes AST (aspartate aminotransferase) and ALT (alanine aminotransferase) in the blood of animals of all groups were within the normal range, which indicates the absence of toxic properties of the consumed products and does not contribute to an increase in cytolysis.

The use of the developed product in the diet reduced the negative effect of alloxan on pancreatic β-cells. A decrease in lipids and cholesterol in the blood of the 3rd experimental group of animals was recorded; apparently, this is due to the presence of antioxidant substances in the biologically active composition (primarily in brewer’s yeast).
5. Conclusion
1. The analysis of research literature allowed suggesting the components and developing the biologically active composition with modified brewer’s yeast, selenium active, chromium chelate and lecithin.
2. The technology of destructing cell walls in brewer’s yeast by preliminary heat treatment with the enzyme lysozyme and subsequent high-speed homogenization of biomass has been developed.
3. Prototypes of boiled sausages with a biologically active composition were made.
4. The safety and harmlessness of the biologically active composition was confirmed on laboratory animals with alloxan diabetes. On the 28th day of observation, a decrease in the blood glucose of the experimental group by 20.57% was noted as compared with the 7th day of observation.

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