Recipe design and study of quality characteristics of meat-vegetable semi-finished products for nutrition of patients with diabetes mellitus

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Abstract. Product-line expansion and increase in production of functional meat products in order to form a healthy nutrition and improve the nutrition status of the population are the priorities of the state policy. Most of the food for nutrition of patients with diabetes mellitus is made using sugar substitutes which do not always meet the requirements of the diet. Meat semi-finished products intended for patients with diabetes mellitus should be a source of biologically complete protein and vitamins; have reduced content of carbohydrates, fat, salt and calories, take into account metabolic disorders in the body of patients. The formalization of biomedical requirements for semi-finished products for nutrition of patients with diabetes mellitus was carried out, as well as selection of ingredients for the recipe enriched with vegetable components that contribute to the improvement of functional and technological properties and biochemical parameters of model minced meat systems. A computer simulation method was used to design a recipe for semi-finished products enriched with vegetable raw materials with a low glycemic index (GI) that reduce the level of postprandial glucose (PPG). Changes in the biochemical parameters of minced meat containing Jerusalem artichoke and flax seeds were studied. The influence of vegetable raw materials on the reduction of catalase and lipase activity with increase in the activity of amylase in the minced meat system was revealed. A comprehensive assessment of the nutritional value and safety of the designed semi-finished products is given.

1. Introduction

One of the most urgent medical-and-social problems related to the nutrition of the population is the prevalence and steady increase in the morbidity of diabetes mellitus (1).

According to official statistics in Russia the number of people with this diagnosis has increased by 2.5 million people over the 18 years (2000-2018) and by 2019 it is 4.8 million people. Out of the total number type 2 diabetes was found: in adults - 4 237 291; in children – 913; in teenagers - 299. It is type 2 diabetes that is growing at such an accelerated pace, as in the whole world, while the morbidity of type I diabetes has not changed much. So, we can conclude that the main reason for the spread of the disease is a dramatic change in the way of life of all mankind. According to statistics, if the situation develops at the same pace, then by 2025 the number of patients with diabetes mellitus will increase twice, or even 3 times!
When designing products for the prevention of diabetes mellitus, the so-called glycemic index GI (a relative indicator of the effect of carbohydrates in food on changes in blood glucose (blood sugar) is widely used. Therefore, it is important to design meat products enriched with plant sources of raw materials that can significantly slow down the absorption of carbohydrates and increase the content of biologically and physiologically active substances (5.6.7). Posprandial glucose is dangerous for the development of cardiovascular diseases. It is this group of disorders that becomes a frequent cause of death and, in addition, posprandial glucose negatively affects the cognitive function of the brain of elderly patients.

The aim of the study was to design specialized meat-and-vegetable semi-finished products enriched with vegetable ingredients with a minimum glycemic index for nutrition of patients with insulin-dependent diabetes mellitus.

2. Materials and methods

The recipe of comminuted semi-finished products that meet the physiological standards of patients with diabetes mellitus was designed by the authors using computer simulation based on biomedical requirements for the composition. Taking into consideration the diabetic orientation of semi-finished products, they should have the following composition: protein - 15-20%, fat - 25-30%, carbohydrates - 50-60%. The latter should be slowly digested and slowly absorbed. The ratio of amino acids should be close to the standards recommended by FAO (Food and Agricultural Organization)/WHO (World Health Organization).

Manufacturing of semi-finished products was carried out in the conditions of ESPC (Educational-Scientific-Production Complex) "Pishchevik" of Saratov State Vavilov Agrarian University. The recipe of experimental samples of semi-finished products included turkey fillet and beef liver in the cooled state. To increase the nutritional value of the protein component, chicken eggs, flax seeds, and leeks were added. These vegetable ingredients have a low glycemic index and enrich semi-finished products with vitamins and microelements. Jerusalem artichoke, which facilitates the absorption of natural insulin by cells, and flax seeds, which enrich the semi-finished products with dietary fibers were included in the recipe of the semi-finished product to reduce the level of posprandial glucose. Semi-finished products designed without including vegetable ingredients were used as control.

Designed semi-finished products were studied using 7 methods: physical and chemical characteristics of semi-finished products – pH, buffer capacity; protein metabolism indicators and enzymes – non-protein nitrogen, creatine, creatinine, activities of catalase, amylase and lipase; carbohydrate metabolism indicators – glucose, glycogen, sialic acids, phosphoenolpyruvate and phosphotrioses; lipid metabolism parameters – cholesterol and low-density lipoproteins.

The authors used modified methods of analysis of meat products that meet the up-to-date methodology of comprehensive assessment of functional products. These methods are modified in the laboratory of Saratov State Vavilov Agrarian University and adapted for muscle tissues (9).

To obtain accurate biochemical data, the correct preparation of extracts from minced meat and meat products is essential. The authors performed the extraction of proteins from muscle tissue (EMT) with a solution of potassium chloride, which facilitated the extraction of both myofibrillar and sarcoplasmic proteins.

The recipe of the semi-finished product was carried out by the simplex-method.

To confirm the preventive effect of the designed semi-finished products, glycemic index was calculated, which is a relative indicator of the effect of carbohydrates in food on changes in blood glucose levels. The method of determination (GI) is regulated by the international standard ISO 26642:2010 (6).

2.1. The value of the buffer capacity

The value of the buffer capacity is determined by the amount of mg-equivalent (mg-EQ) of strong acid or alkali that is necessary to add to 1 liter of buffer solution to change the pH value per unit. For this 1 ml of EMT is measured out in a test-tube, 2 drops of phenolphthalein is added and shaken. Then, the
content of the test-tube is titrated with 0.1 N of sodium hydroxide solution until a faint-pink color appears. The PH of the medium in EMT was pre-determined. Knowing these values the buffer capacity of the protein extract from the muscle tissue is calculated using the formula:

\[ B = a / (pH_2 - pH_1), \]

where \( a \) (mg-EQ) - the amount of 0.1 N of \( \text{NaOH} \) that was used to titrate 1 ml of EMT.

**Non-protein** nitrogen is the nitrogen of organic and inorganic compounds that remains in solution after precipitation of proteins: urea, free amino acids, creatine and creatinine, ammonium salts, etc. To determine the amount of non-protein (residual) nitrogen, a protein-free filtrate obtained after precipitation of EMT proteins was used, which was burned in a Kjeldahl flask after adding concentrated sulfuric acid. The resulting ammonium sulfate in interaction with the Nessler reagent gives a yellow staining, the intensity of which was measured on a photoelectrocalorimeter KFK-2. Then the amount of nitrogen in the sample was determined using a pre-constructed calibration curve.

**Creatinine** – the principle of the method is that creatinine, when interacting with picric acid in an alkaline medium, forms colored compounds whose color intensity is directly proportional to the concentration of creatinine. To convert creatine into creatinine, it is boiled in a solution of hydrochloric acid. In other words, the creatine and creatinine content can be quantified in a single sample. A modification of the method is in determining creatine and creatinine in a protein-free extract, for this 0.5 g of finely comminuted minced meat or meat product is placed in a test-tube with 5 ml of cold trichloroacetic acid (TCA) solution and extracted on ice for 10 minutes, stirring intensively with a glass rod. Then 5 ml of distilled water is added to the mixture and filtered through a paper filter. To determine the creatinine content, 0.2 ml of a 12.5% \( \text{NaOH} \) solution, 2 ml of distilled water, and 0.2 ml of filtrate are sequentially filled into a test-tube. The content of the test-tube is mixed and placed in a boiling water bath for exactly 3 minutes. After cooling, 0.6 ml of a strong solution of picric acid and 1 ml of alkali is added into the test-tube. The test-tube is left to stand for 10 minutes. After this time, 6 ml of H2O is added into it, the content of the test-tube is thoroughly mixed and the color intensity is measured on a photoelectrocalorimeter with a blue light filter. According to the calibration graph, constructed with 0.5 N solution of potassium bicarbonate, its quantitative content in the sample is found. To determine creatinine, the filtrate is pre-boiled for 10 minutes with 0.2 ml of concentrated \( \text{HCl} \) and then creatinine is determined in the same sample.

**Lipase** – Important intermediate products of glucose oxidation are phosphotrioses - glyceraldehyde-1-phosphate and dihydroxyacetonephosphate. Phosphotrioses in an alkaline medium at room temperature are easily hydrolyzed with the release of inorganic phosphate, by the amount of which the content of phosphotrioses is estimated. Since this method is used relatively rarely, we will give it in detail. 0.5 g of comminuted tissue (minced meat, sausage) is placed in a test-tube with 5 ml of cold 2.5% trichloroacetic acid solution and extracted on ice for 10 minutes, stirring intensively with a glass rod. Then 5 ml of distilled water is added to the mixture and filtered through a paper filter. 1 ml of protein-free filtrate is placed into the experiment test-tube and 1 ml of the NaOH solution is added. The content of the test-tube is mixed and left to stand for 20 minutes, then 1 ml of 2 mol/L hydrochloric acid solution is added into the test-tube to neutralize the alkali and the liquid is stirred. 1 ml of \( \text{KaOH} \) solution and 1 ml of \( \text{HCl} \) solution is placed into the control test-tube, the mixture is stirred and only then 1 ml of protein-free filtrate is added. The content is stirred again. 0.5 ml of 1% solution of ammonium molybdate and 0.5 ml of freshly prepared 1% solution of ascorbic acid is added to the experiment and control test-tubes. The total volume of the mixture in both test-tubes is made up with distilled water to 10 ml. The samples are left to stand at room temperature for 10 minutes, after which they are measured on the photoelectrocalorimeter in cuvettes with a layer thickness of 1 cm, with a red light filter. Experimental sample is measured against a control sample and the phosphorus content in the sample is calculated using a calibration curve.
2.2 Statistical processing
Statistical processing of the obtained results on the dynamics of changes in hematological and biochemical parameters of blood serum and urine parameters was performed according to the standard procedures, using the Microsoft Excel 2010 application (Microsoft Corp. USA) and the statistical data analysis package StatPlus 2009 Professional 5.8.4 for Windows (StatSoft Inc., USA) as well as using the Student's t-test to estimate the significance of differences between the samples for experimental and control experiments. Based on the results of calculating the arithmetic-mean and standard deviation for this sample, the standard error of the arithmetic-mean was determined as well as its confidence limits, taking into account the Student's coefficient t (n,p) at a significance level of 95% (p = 0.05) and the number of measurements. The significance of differences between the mean values in experimental and control experiments was estimated by the p-value in the two-sample unpaired t-test with unequal variances. The differences were considered significant when the inequality P ≥ 0.05 was met. In addition, in these cases, we also monitored if the inequality t, t (n, p) at n = (df +1) is met (where df – the number of degrees of freedom), p = 0.05, where:

\[ t = \frac{|x_1 - x_2|}{(\sigma_1^2 + \sigma_2^2)^{1/2}} \]  

(2)

where x1 and x2 – the arithmetic mean values, s1 and s2 are their standard errors for two samples of experimental data [9].

3. Research result
When developing the recipe for semi-finished products, we relied on the principles of food combinatorics, taking into account the possibility of chemical interaction of ingredients, chose such combinations, methods of addition and processing that provided their increased bioavailability, as well as maximum safety during production and storage (1). In this regard, when designing the semi-finished product recipe, a possible range of variation for meat and vegetable ingredients was selected for each of the indicators.

Using the simplex-method, a semi-finished product recipe was designed to reduce the level of postprandial glucose.

Table 1. Ingredient composition for calculating the recipe of a semi-finished product for nutrition of patients with diabetes mellitus

| Product, per 100 g | Possible range of variation, % | Protein content, % | Calorie content, kcal | GI | Cost of ingredient, RUB/100 g |
|-------------------|-------------------------------|--------------------|----------------------|----|-----------------------------|
| X_1 Turkey fillet  | 50…70                         | 20.08              | 116.65               | 0  | 32                          |
| X_2 Beef liver    | 10…30                         | 27.34              | 259                  | 50 | 25                          |
| X_3 Chicken eggs  | 1…3                           | 11.1               | 44                   | 48 | 8                           |
| X_4 Flax seeds    | 1…3                           | 18.29              | 534                  | 77 | 17.2                        |
| X_5 Jerusalem artichoke | 15…20          | 1.55               | 61                   | 50 | 8                           |
| X_6 Leek          | 3…5                           | 1.50               | 61                   | 15 | 9                           |
| X_7 Marrow        | 3…5                           | 0.60               | 24                   | 15 | 4                           |
| X_8 Salt          | 0.7…1                         | 0                  | 0                    | 0  | 1.3                         |

x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 – desired specific weight of inclusion of each raw material in the product.

It is necessary to find the desired values of x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, at which

\[ F(x) = 0 x_1 + 50 x_2 + 48 x_3 + 77 x_4 + 50 x_5 + 15 x_6 + 15 x_7 + 0 x_8. \]

Let us find Fmin(x) if the following conditions are met:
1) Energy value is not more than 150 kcal:

\[116.65x_1 + 259x_2 + 44x_3 + 534x_4 + 61x_5 + 24x_7 + 0x_8 \leq 150.\]

2) The cost of the finished product is not more than 35 RUB/100 g

\[32x_1 + 25x_2 + 8x_3 + 17.2x_4 + 8x_5 + 9x_6 + 4x_7 + 1.3x_8 \leq 35.\]

3) Availability of at least 12% protein in the product produced:

\[20.08x_1 + 27.34x_2 + 11.1x_3 + 18.29x_4 + 1.55x_5 + 1.50x_6 + 0.60x_7 + 0x_8 \geq 12.\]

4) The ratio of the quantity of each type of raw material in 100 g of product (100g=100%):

\[x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 = 100\% = 1.\]

5) Settings of lower constraints on variables:

\[x_1 \geq 50; \quad x_2 \geq 10; \quad x_3 \geq 1; \quad x_4 \geq 1; \quad x_5 \geq 15; \quad x_6 \geq 3; \quad x_7 \geq 3; \quad x_8 \geq 0.7.\]

6) Settings of upper constraints on variables:

\[x_1 \leq 70; \quad x_2 \leq 30; \quad x_3 \leq 3; \quad x_4 \leq 3; \quad x_5 \leq 20; \quad x_6 \leq 5; \quad x_7 \leq 5; \quad x_8 \leq 1.\]

Let's write the problem in canonical form, i.e. we will rewrite the constraints-inequalities as equalities, adding balance variables:

\[0x_1 + 50x_2 + 48x_3 + 77x_4 + 50x_5 + 15x_6 + 15x_7 + 0x_8 - z = 0;\]

\[116.65x_1 + 259x_2 + 44x_3 + 534x_4 + 61x_5 + 61x_6 + 24x_7 + 0x_8 + s_1 = 150;\]

\[32x_1 + 25x_2 + 8x_3 + 17.2x_4 + 8x_5 + 9x_6 + 4x_7 + 1.3x_8 + s_2 = 35;\]

\[20.08x_1 + 27.34x_2 + 11.1x_3 + 18.29x_4 + 1.55x_5 + 1.50x_6 + 0.60x_7 + 0x_8 - s_3 = 0.12;\]

\[x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 = 100\% = 1;\]

\[x_1 - s_4 = 0.5; \quad x_2 + s_{13} = 0.3;\]

\[x_2 - s_5 = 0.1; \quad x_3 + s_{14} = 0.03;\]

\[x_3 - s_6 = 0.01; \quad x_4 + s_{15} = 0.03;\]

\[x_4 - s_7 = 0.01; \quad x_5 + s_{16} = 0.2;\]

\[x_5 - s_8 = 0.15; \quad x_6 + s_{17} = 0.05;\]

\[x_6 - s_9 = 0.03; \quad x_7 + s_{18} = 0.05;\]

\[x_7 - s_{10} = 0.03; \quad x_8 + s_{19} = 0.01;\]

\[x_8 - s_{11} = 0.007; \quad x_i \geq 0. \quad s_j \geq 0. \quad i = 1,...,8. \quad j = 1,...,19.\]

\[x_1 + s_{12} = 0.7;\]

This system is a system with a basis (basis s1, s2,... s19), each of them is included only in one equation of the system with a coefficient of 1 and x1,..., x8 - are free variables. Problems that use the simplex-method must have the following two properties: - the constraint system must be a system of equations with a basis; - the free terms of all equations in the system must be non-negative. The resulting system is a system with a basis and its free members are non-negative, so you can apply the simplex-method.

The solution of this problem is carried out using the simplex-method of the Solution Search package of the MS Excel 2007 application shown in Figure 1.
Figure 1. Fragment of the MS Excel 2007 application worksheet with source data, initial (zero) values of variables, objective function and constraints

Figure 2. Fragment of the MS Excel 2007 application worksheet with source data, objective function formulas and constraints

Figure 3. Parameters for solution search of MS Excel 2007 application with the addresses of objective function, variables and constraints
The result of the program calculation was $x_1 = 0.66; x_2 = 0.10; x_3 = 0.01; x_4 = 0.01; x_5 = 0.15; x_6 = 0.03; x_7 = 0.03; x_8 = 0.01$.

Based on the obtained data, a multiplicative model of the ratio of ingredients is compiled, as shown in Figure 5.

For patients with diabetes, it is preferable to use food with a low glycemic index, GI of food products is the physiological basis of carbohydrate metabolism (5).
From numerous group studies conducted around the world, it is known that for 20% of people whose diet has the lowest GI, its value is in the range of 40-50.

Experimental research of Diabetes Care, which studied the effects of low-glycemic diets, showed significant benefits for patients with diabetes, whose average daily GI did not exceed 45. The Glycemic Index Foundation researcher found that the GI should be 45 or lower when developing food recipe for the patients with type II diabetes.

Long-term use of products that have a low GI leads to a decrease of posprandial glucose levels in blood, which, ultimately, will reduce the risk of insulin-dependent diabetes as well as diseases of the cardiovascular system.

The study of semi-finished products for the nutrition of patients with diabetes mellitus showed that the introduction of vegetable ingredients in the recipe led to a slight decrease in pH - from the 1st to the 10th day of the experiment, on average, by 0.14; 0.26; 0.24 and 0.05 units, respectively.

As known, the buffer capacity characterizes the ability of the buffer system to resist changes in the pH of the medium when adding strong acid or alkali. The buffer capacity of the product is important in the diet to maintain the acid-base balance of the digestive tract.

Studies have shown that inclusion of Jerusalem artichoke in the recipe of the designed semi-finished products leads to an increase in the buffer capacity. So, after one day, the buffer capacity increased to 3.30 ± 0.09 (P < 0.001), after two days - to 2.88 ± 0.01 (P < 0.01), after five days - to 2.42 ± 0.01(P < 0.05) and after ten days - to 2.23 ± 0.05 mg-EQ (P < 0.05), compared with minced meat without addition of Jerusalem artichoke. This is important because the increase in the buffer capacity enhances the body's ability to dispose such semi-finished product. The inclusion of vegetable ingredients in the recipe activates the disintegration and transformation of protein compounds of semi-finished products for the nutrition of patients with diabetes, indirect evidence of which is an increase in the content of residual nitrogen.

The concentration of non-protein nitrogen is an important indicator that indirectly estimates the intensity of proteolysis.

The results of the studies showed that the level of non-protein nitrogen in the designed semi-finished products with vegetable biological additives was respectively 39.2 ± 3.7; 38.5 ± 4.0; 27.1 ± 1.6 and 21.1 ± 0.7 mg/g. This, compared to the control sample, was higher by 19.1; 19.2; 30.9 and 68.8%, respectively. These results allowed us to state that the enrichment of the recipe with vegetable ingredients increases the breakdown of protein compounds in semi-finished products, resulting in an increase in the content of the final products of nitrogen metabolism.

Creatinine is one of the final products of nitrogen metabolism, it is an anhydride of creatine. About 80 % of creatine is found in muscles. When it interacts with adenosine triphosphate (ATP), creatine phosphate is formed, which contains stored energy consumed during muscle contraction.

Enrichment of the designed recipe of semi-finished products with vegetable raw materials corrected creatine and creatinine content in them during storage (Table 2).

| Indicators/ days | Creatine       | Creatinine     | Creatine/creatinine index |
|------------------|----------------|----------------|---------------------------|
| 1                | 14.30 ±2.32    | 14.00 ±0.15    | 1.00                      |
| 2                | 13.80 ± 1.88   | 13.70 ± 0.12   | 1.00                      |
| 5                | 11.50 ± 1.23   | 12.00 ±0.10    | 0.95                      |
| 10               | 9.30 ±0.04     | 5.00 ±0.05     | 1.90                      |

The inclusion of vegetable ingredients in the designed recipe of semi-finished products contributed to the overall decrease in creatine content, which decreased slightly in the dynamics of storage, but
was statistically significant (Table 2) – 10th day (P<0.02). As for creatinine, it was quite high and statistically significantly decreased only by the 10th day (P<0.001).

Naturally, the heat treatment reduced the activity of the studied enzymes. However, if vegetable ingredients were added into semi-finished products, their activity was higher than in the control group. For example, catalase activity has exceeded the control data by 40.0% by the 1st day of observation, amounting to 0.07±0.01; by 2nd day - by 0.0%, equal to 0.06±0.01; by the 5th - by 50.0% and was equal to 0.03±0.007 units. By the 10th day of the experiment, the catalase activity calculated as a catalase number was the same in both compared groups and was at a low level (0.017±0.001 and 0.018±0.001 units).

Within the period of studies, amylase activity was also higher in semi-finished products enriched with vegetable ingredients, although its activity decreased slightly by the days of observation: by the 5th day - by 25.0% and by the 10th day - by 40.0%. Compared to semi-finished products without vegetable raw materials, these changes were as follows. By the end of the 1st day of storage, the amylase activity in the experimental batch of semi-finished products was 20.0±4.5 ml of 0.1% starch or by 66.7% higher than in the control. By the 2nd day of the experiment, these ratios did not change, and by the 5th day, the activity of the enzyme decreased to 15.0±3.37, but it continued to be higher than in the control batch of semi-finished products by 66.7%; by the 10th day, these ratios were 12.0±2.25 and by 84.6%. These results may indicate a more significant breakdown of high-molecular-weight starchy raw materials into low-molecular-weight products under the influence of vegetable raw materials.

Tables 3-6 show the dynamics of lipase activity in semi-finished products enriched with vegetable ingredients.

Table 3. Dynamics of lipase activity in semi-finished products enriched with vegetable raw materials (1st day)

| Incubation time, hour | Volume 0.001 mol/L NaOH, used for titration, ml |
|-----------------------|-----------------------------------------------|
|                       | Extract | Extract + bile | Extract + Pancreatin | Extract + bile + Pancreatin |
| 0                     | 0.90±0.17 | 1.03±0.23 | 0.89±0.15 | 1.00±0.21 |
| 1                     | 0.90±0.14 | 1.07±0.21 | 0.93±0.14 | 1.04±0.19 |
| 2                     | 0.95±0.14 | 1.08±0.22 | 0.98±0.12 | 1.09±0.19 |
| 3                     | 0.95±0.01 | 1.11±0.21 | 0.99±0.12 | 1.14±0.20 |

Table 4. Dynamics of lipase activity in semi-finished products enriched with vegetable raw materials (2nd day)

| Incubation time, hour | Volume 0.001 mol/L NaOH, used for titration, ml |
|-----------------------|-----------------------------------------------|
|                       | Extract | Extract + bile | Extract + Pancreatin | Extract + bile + Pancreatin |
| 0                     | 0.84±0.14 | 0.98±0.24 | 0.85±0.14 | 0.98±0.22 |
| 1                     | 0.86±0.15 | 1.03±0.24 | 0.90±0.14 | 1.01±0.21 |
| 2                     | 0.91±0.15 | 1.07±0.23 | 0.96±0.14 | 1.08±0.21 |
| 3                     | 0.91±0.15 | 1.13±0.22 | 0.96±0.12 | 1.10±0.19 |
Table 5. Dynamics of lipase activity in semi-finished products enriched with vegetable raw materials (5th day)

| Incubation time, hour | Volume 0.001 mol/L NaOH, used for titration, ml |
|-----------------------|-----------------------------------------------|
|                       | Extract | Extract + bile | Extract + Pancreatin | Extract + bile + Pancreatin |
| 0                     | 0.83±0.13 | 0.95±0.25 | 0.83±0.12 | 0.95±0.21 |
| 1                     | 0.83±0.13 | 0.99±0.24 | 0.86±0.12 | 1.00±0.19 |
| 2                     | 0.86±0.11 | 1.04±0.24 | 0.93±0.13 | 1.05±0.19 |
| 3                     | 0.86±0.11 | 1.10±0.20 | 0.93±0.13 | 1.08±0.18 |

Table 6. Dynamics of lipase activity in semi-finished products enriched with vegetable raw materials (10th day)

| Incubation time, hour | Volume 0.001 mol/L NaOH, used for titration, ml |
|-----------------------|-----------------------------------------------|
|                       | Extract | Extract + bile | Extract + Pancreatin | Extract + bile + Pancreatin |
| 0                     | 0.76±0.09 | 0.93±0.23 | 0.79±0.12 | 0.90±0.21 |
| 1                     | 0.78±0.12 | 0.94±0.24 | 0.81±0.11 | 0.94±0.19 |
| 2                     | 0.81±0.09 | 0.99±0.24 | 0.86±0.11* | 0.98±0.13 |
| 3                     | 0.83±0.11 | 1.01±0.22 | 0.88±0.11 | 0.99±0.17 |

From Tables 3-6 it can be seen that lipase activity in semi-finished products containing vegetable raw materials of hypoglycemic action was not more than 22.6-28.2% (10th days of each variant of experiment) of the enzyme activity in the corresponding minced meat. Moreover, the most significant activity of lipase was induced by bile.

In subsequent experiments, the authors studied changes in some indicators of carbohydrate metabolism in semi-finished products for patients with diabetes after they were enriched with vegetable raw materials. In water extracts of experimental semi-finished products, the free glucose content was 1.06±0.04 (mol/L) a day after the beginning of the experiment. This is slightly higher than in the comparable group of semi-finished products but without vegetable raw materials, by 10 mmol/L, and the data are statistically significant (P <0.05). This trend continued throughout the experiment. So, by 2nd day the glucose content in the extract of semi-finished products with vegetable raw materials for patients with diabetes was 1.02±0.04 mmol/L (P<0.05), by 5th day of the experiment - 0.95±0.07 mmol/L (P<0.05) and by 10th day - 0.70±0.08 mmol/L (P>0.1). These data are consistent with sufficiently high glycogen content in samples of semi-finished products, in the recipe of which vegetable ingredients were added. Although its level in the experimental batch of semi-finished products gradually decreased from the 1st to the 10th day of storage and ranged from 1.47±0.04 to 2.16±0.08 mg/g. However, the glycogen content was almost always slightly higher than in the semi-finished products of the control group.

At the same time, the phosphotrioses content, on the contrary, after enrichment of semi-finished products with vegetable ingredients was lower than in the control. So, by the 1st day, the differences were 0.02 mg/g, by the 2nd day - 0.03 mg/g, by the 5th day-0.04 mg/g and by the 10th day - 0.09 mg/g. This trend was typical for phosphoenolpyruvic acid, with the exception of the 10th day of the experiment. So, in the first three storage periods, the content of phosphoenolpyruvic acid in the experimental batch of semi-finished products was lower than the control by 0.05 mg/g, by the 10th day, on the contrary, it was higher by 0.1 mg/g.

The correlation of the described indicators of carbohydrate metabolism is shown in Figure 6.
Figure 6. Indicators of carbohydrate metabolism

From Figure 6 it can be seen that all the determinable indicators, except for phosphoenolpyruvic acid, gradually decreased in the course of storage, reflecting the metabolic processes and the quality of semi-finished products for patients with diabetes.

From the point of view of nutrition science it is high-potential that after the enrichment of semi-finished products with vegetable ingredients of hypoglycemic action, their cholesterol content decreased and it continued to fall with extension of the shelf life of the semi-finished products. At the same time low-density lipoprotein content in the semi-finished products of the experimental batch also decreased (Figure 7).

Figure 7. Low-density lipoprotein content in the designed semi-finished products

This phenomenon was typical, as described above, and for minced meat with a vegetable additive. However, in semi-finished products, the intensity of reducing the content of cholesterol and low-density lipoprotein was less significant than in minced meat.

4. Conclusion
Using the simplex-method, the recipe for semi-finished products enriched with vegetable ingredients that reduce the level of postprandial glucose for nutrition of patients with insulin-dependent diabetes mellitus was designed.
Enrichment of semi-finished products for patients with diabetes mellitus with vegetable ingredients stabilized the pH of products, increased their buffer capacity, facilitated greater breakdown of protein substances and their transformation into nitrogenous compounds, maintained the activity of catalase, amylase and lipase within certain limits, caused the breakdown of glycogen and a certain increase in glucose as well as reduced the concentration of low-density lipoproteins.

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