Designing a fermented sausage recipe for a healthy balanced diet

T M Giro¹, E V Berdnova¹, V A Tokareva¹, V P Korsunov¹ and E N Korsunova²

¹ Saratov State Agrarian University named after N.I. Vavilov, Saratov, Russia
² Saratov State Medical University named after V. I. Razumovsky, Saratov, Russia

E-mail: girotm@sgau.ru

Abstract: The formalization of biomedical requirements for fermented sausages for healthy and balanced nutrition was carried out, along with the selection of the ingredients for the recipe, which are enriched with components that improve the functional and technological properties. Using the method of computer simulation, there has been designed a recipe for fermented sausages enriched with an organic additive which reduces the residual level of sodium nitrite.

1. Introduction
The production of fermented sausages is a scientific, comprehensive justification of the technology of food products using an innovative recipe which includes ingredients reducing the residual amounts of nitrite curing mixture. In this situation, the development of recipes and production of meat products are of particular importance, since it becomes possible to produce products enriched with almost all the necessary minerals and vitamins.

2. Purpose of research
Is to select the structure of ingredients of products included in the production of dry-cured sausage that corresponds to a healthy lifestyle and design a recipe.

3. Research methods
To design the recipe for fermented sausage products, we used the simplex method in the Excel computer program.

4. Research result
The quality of food depends on the current unfavourable economic trend of rise in prices for many goods, which outstrips the growth in the real purchasing power of population income [3]. There is a rise in prices for natural essential food (meat, fish, milk, fresh fruits and vegetables), which means that they are becoming economically unaffordable for citizens. However, in this situation, one should not forget about the need to regularly replenish the body’s energy consumption, not only with carbohydrates, but also with proteins, fats, vitamins, and minerals [2, 4].

Organic products are recommended for health, diet and baby food. Products in this category are produced using environmentally friendly technologies. [1, 6].

It is forbidden to use genetically modified ingredients in the series of these products; it is permissible to use only natural additives and flavourings. It is recommended not to include preservatives and...
colorants in the recipe. Raw meat should be grown without the use of antibiotics, hormones and enzymes in the diet.

Naturally, all these products do not contain any chemicals which are present in the composition of conventional products. This is the main benefit of organic products for people. Moreover, these natural products also contain a large amount of nutrients, namely iron, calcium, manganese, magnesium, amino acids, beta-carotene, vitamins C, D, B, etc [7].

The main feature of the technology is the use of domestic raw materials of animal and vegetable origin, starter cultures, and the absence of additives (artificial colorants and preservatives) which have a negative impact on human health. The amount of salt, fat and nitrite-curing mixture is limited in sausages.

The product is classified as environmentally friendly, since its technology excludes smoking, during which carbonyl compounds, furfural and other toxic substances with carcinogenic properties are formed.

The composition of the main food ingredients is known, as well as the indicators that characterise them. In general, these indicators are mostly studied [5] and they are presented as indicated in table 1.

Table 1. The ratio of trace elements in the food products used.

| Trace elements, mg: | Beef | Lean pork | Pork belly | Cedar nuts | Powdered milk | Salt | Daily human intake, mg |
|---------------------|------|-----------|------------|------------|---------------|------|------------------------|
| Potassium (K)       | 355  | 279       | 378        | 595        | 1330          | 8    | 2500-5000              |
| Calcium (Ca)        | 10.2 | 9         | 7          | 18         | 912           | 24   | 800                    |
| Magnesium (Mg)      | 22   | 19        | 26         | 254        | 85            | 1    | 400                    |
| Phosphorus (P)      | 188  | 178       | 229        | 573        | 776           | 0    | 1200                   |
| Iron (Fe)           | 2.9  | 2.5       | 0.9        | 5.8        | 0.5           | 0    | 14                     |

Below there is offered a specific fermented product, i.e. dry-cured sausage. To produce it, it is necessary to develop a balanced structure of ingredients from the proposed products, which correspond to a healthy lifestyle. The solution to this problem depends on the strategy with which to approach it, and on the methodology for tackling it. In this case, the problem will be solved using the simplex method.

Hence, we set up the following task: to select the structure of the ingredients of the products included in the production of dry-cured sausage, corresponding to a healthy lifestyle. The limits of the acceptable components corresponding to a healthy lifestyle are shown in table 1. It is necessary to select such a quantity of ingredients of the products so that they fit into the limits of acceptable values.

Table 2 shows the data on the content of trace elements in dry-cured sausage "Florence" in 100 g of the product.

Table 2. The ratio of trace elements in 100 g of the sausage and in daily intake.

| Trace elements (g) | K      | Ca       | Mg            | P              | Fe                | Calorie content (kcal) |
|--------------------|--------|----------|---------------|-----------------|-------------------|------------------------|
| Content per 100 grams of dry-cured sausage | 0.364-0.366 | 0.078-0.079 | 0.028-0.029 | 0.0745-0.0755 | 0.0369-0.0371 | 538 |
| Daily human intake | 2.5-5  | 0.8      | 0.4           | 1.2             | 0.014             | 2550                   |

We will bring all the data to a single ratio: to 100 g of product per day. The daily intake of food mass for a person (without water) (according to Pokrovsky) is 1000 g. In this case, 100 g of sausage will be
0.1 of the daily intake. We will calculate and bring the data of tables 1 and 2 to the 0.1 of the daily intake, the data will be summarized in table 3.

Table 3. Indicators of trace elements reduced to 0.1 of daily intake.

| Trace elements       | Potassium (g) | Calcium (g) | Magnesium (g) | Phosphorus (g) | Iron (g) |
|----------------------|---------------|-------------|---------------|----------------|----------|
| Content per 100 grams of boiled sausage | 0.243 | 0.029 | 0.022 | 0.178 | 0.002 |
| Daily human intake   | 0.25-0.5      | 0.08        | 0.04          | 0.12           | 0.0014   |
| Beef                 | 0.355         | 0.0102      | 0.022         | 0.188          | 0.0029   |
| Lean pork            | 0.279         | 0.0099      | 0.019         | 0.178          | 0.0025   |
| Pork belly           | 0.378         | 0.007       | 0.026         | 0.229          | 0.009    |
| Cedar nuts           | 0.595         | 0.018       | 0.254         | 0.573          | 0.0058   |
| Powdered milk        | 1.33          | 0.912       | 0.085         | 0.776          | 0.0005   |
| Salt                 | 0.008         | 0.021       | 0.001         | 0           | 0        |

Table 4. Ingredients for calculating dry-cured sausage "Florence".

| Product, per 1 g | Possible range of variation | Protein content, gram | Fat content, gram | Carbohydrate content, gram | Calorie content (kcal/gram) |
|------------------|-----------------------------|-----------------------|------------------|-----------------------------|----------------------------|
| X_1 2nd grade beef * | 8-12 | 0.189 | 0.124 | 0 | 1.872 |
| X_2 Lean pork | 55-65 | 0.164 | 0.278 | 0 | 3.158 |
| X_3 Pork belly | 18-23 | 0.08 | 0.633 | 0 | 6.017 |
| X_4 Cedar nuts | 4-5 | 0.1369 | 0.6837 | 0.1308 | 7.2241 |
| X_5 Nitrite ersatz salami | 1 | 0 | 0 | 0 | 0 |
| X_6 Powdered milk | 0.3-0.7 | 0.242 | 0.25 | 0.393 | 4.79 |
| X_7 Starter cultures | 0.02 | 0 | 0 | 0 | 0 |
| X_8 Italian salami | 0 | 0 | 0 | 0 | 0 |
| X_9 Salt | 2.6-2.8 | 0 | 0 | 0 | 0 |

*2nd grade beef consists of meat from the upper parts of cow, e.g. neck, shoulder, flank.

x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9 is the required specific weight of each raw material included in the product.

It is necessary to find the required values of x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 at which F(x) = 0.189x_1 + 0.164x_2 + 0.08x_3 + 0.1369x_4 + 0x_5 + 0.242x_6 + 0x_7 + 0x_8 + 0x_9 → max.

Under the following conditions:

- Energy value should not exceed 538 kcal:
  - 1.872 x_1 + 3.158 x_2 +6.017x_3 + 7.2241x_4 + 0 x_5 + 4.79x_6 + 0x_7+0x_8+0x_9≤538

- The ratio of the amount of each type of raw material in 100 g of the product (100 g = 100%)
- The presence of at least 14% protein in the produced product: F(x)≥14
- Setting the lower constraints on variables:
  - x_1≥8; x_2≥55; x_3≥18; x_4≥4; x_5≥2; x_6≥0.3; x_7≥0.02; x_8≥1; x_9≥2.6

- Setting the upper constraints on variables:
  - x_1≤12; x_2≤65; x_3≤23; x_4≤5; x_5≤3; x_6≤0.7; x_7≤0.02; x_8≤1, x_9≤2.8
This problem is solved by using 'Solver' setting in the MS Excel 2013 application, presented in table 5.

**Table 5.** Fragment of the MS Excel 2013 application worksheet with initial data, initial (zero) values of variables, objective function and constraints.

| Variables | Values of required data | Product | Lower constraints on variables | Upper constraints on variables | Protein content, g | Calorie content, kcal/gram |
|-----------|-------------------------|---------|-------------------------------|-------------------------------|-------------------|---------------------------|
| x1        | 2nd grade beef          | 8       | 12                            | 0.189                         | 1.872             |
| x2        | Lean pork               | 53      | 63                            | 0.164                         | 3.158             |
| x3        | Frozen pork belly       | 18      | 23                            | 0.08                          | 6.017             |
| x4        | Cedar nuts              | 4       | 5                             | 0.1369                        | 7.2241            |
| x5        | Nitrite ersat\(\) salami | 1     | 1                             | 0                             | 0                 |
| x6        | Powdered milk           | 0.3     | 0.7                           | 0.242                         | 4.79              |
| x7        | Starter culture Almi 2  | 0.02    | 0.02                          | 0                             | 0                 |
| x8        | Salt                    | 1       | 1                             | 0                             | /0                |
| x9        | Italian salami № 12829 | 2.68    | 2.8                           | 0                             | 0                 |

Table 6 shows a fragment of the MS Excel 2013 application worksheet with initial data, objective function formulas and constraints.

**Table 6.** Fragment of the MS Excel 2013 application worksheet with initial data, objective function formulas and constraints.

| Variables | Values of required data | Product | Lower constraints on variables | Upper constraints on variables | Protein content, g | Calorie content, kcal/gram |
|-----------|-------------------------|---------|-------------------------------|-------------------------------|-------------------|---------------------------|
| x1        | 2nd grade beef          | 8       | 12                            | 0.189                         | 1.872             |
| x2        | Lean pork               | 53      | 63                            | 0.164                         | 3.158             |
| x3        | Frozen pork belly       | 18      | 23                            | 0.08                          | 6.017             |
| x4        | Cedar nuts              | 4       | 5                             | 0.1369                        | 7.2241            |
| x5        | Nitrite ersat\(\) salami | 1     | 1                             | 0                             | 0                 |
| x6        | Powdered milk           | 0.3     | 0.7                           | 0.242                         | 4.79              |
| x7        | Starter culture Almi 2  | 0.02    | 0.02                          | 0                             | 0                 |
| x8        | Salt                    | 1       | 1                             | 0                             | /0                |
| x9        | Italian salami № 12829 | 2.68    | 2.8                           | 0                             | 0                 |

Objective function: 0.0000
Constraints: 0.0000

Objective function: 14.3634
Constraints: 354.3942
100.0000
Figure 1 shows the solver parameters in the MS Excel 2013 with the addresses of the objective function, variables and constraints.

The result of the application calculation is the following: $x_1 = 12; x_2 = 60.6; x_3 = 18; x_4 = 4; x_5 = 1; x_6 = 0.7; x_7 = 0.02; x_8 = 1; x_9 = 2.68$.

Based on the data obtained, a multiplicative model of the ratio of components was compiled and is shown in figure 2.

**Figure 2.** Multiplicative model of the ratio of components in the recipe for dry-cured sausage "Florence" $x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9 = 12+60.6+18+4+1+0.7+0.02+1+2.68 = 100$. 
5. Conclusion
Using the simplex method, the fermented sausage recipe was designed to reduce the level of residual sodium nitrite. The proposed recipe for fermented sausages meets the stated purpose and is, therefore, recommended for appropriate use.

References
[1] Giro T M and Tokareva V A 2019 Stabilisation of the colour of dry-cured sausages using sodium nitrite in organic form Mezhd. n-p konf. «Perspektivnye agrarnye i pishevyye innovatsii» (Volgograd) 56-7
[2] If you spend less than 10 thousand on food a month, then you are undernourished Electronic resource Internet newspaper "Gazeta.ru" – Available at: URL: https://www.gazeta.ru/comments/column/mironova/10527365.shtml (Accessed on 20.10.2020)
[3] The project "Fundamentals of the state policy of the Russian Federation in the field of healthy nutrition for the period until 2020" Electronic resource Available at: https://rg.ru/2010/11/03/pravila-dok.html (Accessed on 23.10.2020)
[4] Chernukha I M, Fedulova LV and Dydykin A S Safe and healthy foods as the main factor determining the quality of life Vse o miase 2 20-2
[5] Nesterina M F and Skurikhina I M 2001 The chemical composition of food Spravochnye tablitsy soderzhaniia aminokislot, zhirnykh kislot, vitaminov, makro- i mikroelementov, organicheskikh kislot i uglevodov (Moscow: Pishchevaia promyshlennost’) p 3
[6] Fransen H P, Boer J MA, Beulens J WJ, de Wit G A, Bueno-de-Mesquita H B, Hoekstra J, May A M and Peeters P H M 2017 Associations between lifestyle factors and an unhealthy diet Eur J Pub Health. 27 274-8
[7] Jody C Hoenink, Joline W J Beulens, Marjolein C Harbers, Jolanda M A Boer, S Coosje Dijkstra, Mary Nicolaou, Yvonne T. van der Schouw, Ivonne Sluijs, W M Monique Verschuren, Wilma Waterlander and Joreintje D. Mackenbach 2020 To what extent do dietary costs explain socio-economic differences in dietary behavior? Nutrition Journal 19 88