Application of mathematical modeling and the principles of qualimetric forecasting in the production of semi-finished horse meat products with the use of a protein fortifier

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Abstract. Meat products are a key part of human nutrition. It is necessary to introduce and apply new, extraordinary solutions to the problems of improving technological processes and developing optimal technologies for processing raw materials of animal origin, taking into account the biological risks at the enterprise. One of the ways to improve production technology is by using mathematical modeling and qualimetric forecasting. Semi-finished meat products are in high demand among the population lately. The purpose of the research is the application of mathematical modeling and the principles of qualimetric forecasting in the production of semi-finished horse meat products with the use of a protein fortifier. The appearance is characterized by the most significant coefficients of organoleptic assessment – 44.2%, and flavor – 15.1%. The use of mathematical modeling in assessing consumer preferences of customers and the quality of food products gives a fairly objective end result.

1. Introduction

Today, in the field of processing and storage of agricultural raw materials and products based on it, technologies are insufficiently consistent with modern scientific achievements. It is necessary to introduce and apply new, extraordinary solutions to the problems of improving technological processes and developing optimal technologies for processing raw materials of animal origin, taking into account biological risks at the enterprise and optimal technologies for processing valuable raw meat [1–4]. One of the ways to improve production technology is the use of mathematical modeling and qualimetric forecasting.

One of the most important priority directions in the development of the meat industry is the development of new types of food products with the use of all types of protein-containing raw materials [5–8].

Consumers of meat products are concerned about the increasing deterioration in the sensory characteristics of food of animal origin, especially the taste of meat products. When designing innovative types of food, including food of animal origin, taking into account the expectations and requirements of consumers of meat products, in our opinion, is very important [9–11]. One of the ways to solve this topical issue can be the principle of qualimetric forecasting.
The qualimetric model for predicting the quality of food products allows, even at the stage of development and design of food products of animal origin, to determine the range of indicators of quality and safety of products that would meet the expectations and growing needs of consumers of meat products.

2. Material and Methods
We have developed the technology and formulation of a protein fortifier and minced semi-finished horse meat product. On the basis of the studies carried out, the normative technical documentation for the minced semi-finished product with addition of a protein fortifier (standard) was approved.

A patent for a useful model of the Republic of Kazakhstan No. 3373 dated 12.11.2018. Method for the production of semi-finished meat products was received. [12].

Experimental-industrial approbation of the developed formulations of technologies was carried out in the production conditions of LLP “Semmol”, Semey (East Kazakhstan region, Republic of Kazakhstan).

The research uses modern generally accepted methods of mathematics, MS Excel.

3. Results and Discussion

3.1 Mathematical modeling of the formulation of a new meat product
When carrying out the research, mathematical modeling of a new meat product was proposed based on modern principles of combinatorics and nutritional science. With known parameters of the ingredients, a formulation composition of a semi-finished horse meat product was made with the use of a protein fortifier with specified quality characteristics. For consumers of meat products (recently) indicators of biological and nutritional value are of undoubted importance.

We offer the following notation:

- \( X_1 \) – the amount of protein fortifier in the meat semi-finished product developed by us;
- \( X_2 \) – the amount of horse meat used in the formulation of the semi-finished product developed by us.

To solve the problem of optimizing the formulation composition of a semi-finished horse meat product with the use of a protein fortifier in terms of protein composition, it is necessary to know the total protein content in each component – \( C_1, C_2 \).

The objective function will linearly depend on the considered components of the prescription composition of a semi-finished horse meat product with the use of a protein fortifier:

\[
F1(x) = \sum_{j=1}^{2} C_j X_j
\]

Thus, we have a linear programming problem.

Let us introduce restrictions to determine the range of feasible solutions to the problem.

According to the content of essential amino acids in the formulation composition of semi-finished horse meat product with the use of a protein fortifier:

\[
\sum_{j=1}^{2} a_{i,j} X_j \geq b_i
\]

where: \( a_{i,j} \) – the content of the \( i \)-th amino acid in the \( j \)-th component of semi-finished horse meat product with the use of a protein fortifier, mg/100 g;

\( b_i \) – recommendations of the Food and Agriculture Organization of the United Nations and the World Health Organization on the content of the \( i \)-th amino acid mg/100 g.

According to the prescription components of semi-finished horse meat product with the use of a protein fortifier:

\[
\sum_{j=1}^{3} X_j = 1,0
\]
\[ X_{j}^{\text{min}} \leq X_j \leq X_{j}^{\text{max}} \]

The total number of components of a semi-finished horse meat product with the use of a protein fortifier was taken as 100%, this is due to the fact that the components not containing protein (water, food salt) were not taken into account in this calculation.

Substituting the value of the coefficients, we obtain a mathematical model of the problem of formulation optimization of semi-finished horse meat product with the use of a protein fortifier:

Objective function:
\[ F_1(X) = 18.8 \cdot X_1 + 19.5 \cdot X_2 \]

Limitations on amino acid composition:
- Valine: \[ 511.21 \cdot X_1 + 996 \cdot X_2 \geq 5000 \]
- Isoleucine: \[ 482.5 \cdot X_1 + 799 \cdot X_2 \geq 4000 \]
- Leucine: \[ 831.11 \cdot X_1 + 1494 \cdot X_2 \geq 7000 \]
- Lysine: \[ 880.18 \cdot X_1 + 1739 \cdot X_2 \geq 5500 \]
- Methionine: \[ 214.65 \cdot X_1 + 473 \cdot X_2 \geq 3500 \]
- Threonine: \[ 451.21 \cdot X_1 + 923 \cdot X_2 \geq 4000 \]
- Tryptophan: \[ 107 \cdot X_1 + 282 \cdot X_2 \geq 1000 \]
- Phenylalanine: \[ 430.73 \cdot X_1 + 857 \cdot X_2 \geq 6000 \]

Restrictions on the formulation components of semi-finished horse meat product with the use of a protein fortifier:
\[ X_1 + X_2 = 1.0 \]
\[ 0.1 \leq X_1 \leq 0.25, \quad 0.6 \leq X_2 \leq 0.75 \]

Having solved the problem by the conjugate gradient method using MS Excel, we get the solution:
\[ X_1 = 0.223529, \quad X_2 = 0.776471 \]

The amount of protein in a semi-finished horse meat product with the use of a protein fortifier with this ratio of components will be 0.191219 g (or 19.12 g/100 g of the developed meat product).

By recalculating for the formulation, taking into account the components that do not contain protein (drinking water and food salt are 15% of the product), we get the total protein content in the product which is 0.162536 g (or 16.25 g/protein in 100 g of the product we have developed).

3.2 Application of principles of qualimetric forecasting in the production of semi-finished horse meat products with the use of protein enrichment on the example of organoleptic indicators

In order to determine consumer preferences for semi-finished minced meat products from the end of October 2018 to the beginning of June 2019, a survey of 312 residents of the city of Semey (East Kazakhstan region, Republic of Kazakhstan) was conducted. 160 women and 152 males took part in this sociological survey. The respondents took part in our research in accordance with the rules for conducting marketing research.

On the example of the developed minced semi-finished horse meat product with a protein fortifier, the definition of the organoleptic assessment of the product quality is shown.

The quality of the minced semi-finished product was assessed by the group of organoleptic indicators (appearance, flavor, color, shape and sectional view). To implement the selection algorithm, we used the information about the type of relationship between each pair of objects and, in particular, about the existence of strict preference relationships between two objects. For this, a relationship variable was introduced.
The proposed technique makes it possible to introduce efficiency criteria for a comprehensive assessment of the developed semi-finished horse meat product with the use of a protein fortifier.

\[ a_{ij} = \begin{cases} 
1, & \text{if } i \text{ option is equivalent to } j \\
3, & \text{if } i \text{ option moderately exceeds } j \\
5, & \text{if } i \text{ option is far superior to } j
\end{cases} \]

**Figure 1.** Matrix of relationships between alternative solutions.

Next, we built a square matrix \([a]\) (table 1) relationships between the solution alternatives.

\[ a_{ji} = \frac{1}{a_{ij}}, \quad a_{ii} = 1 \quad i, j = 1, n \]

**Table 1.** Matrix of relations between alternative solutions (by the example of organoleptic indicators of minced meat semi-finished products).

| a(ij)  | Appearance | Flavor | Taste | Texture | Sectional view |
|--------|------------|--------|-------|---------|----------------|
| Appearance | 1     | 4       | 2      | 3       | 5               |
| Flavor  | 1/4 | 1       | 2      | 4/3     | 4/5             |
| Taste   | 1/2 | 1/2     | 1      | 2/3     | 2/5             |
| Texture | 1/3 | 3/4     | 3/2    | 1       | 5/3             |
| Sectional view | 1/5  | 5/4     | 5/2    | 3/5     | 1               |

**Head vector**

\[ X_j = \sum_{i=1}^{n} a(ij) \]

\[ X_j = 2.283, 7.500, 9.000, 6.600, 8.866 \]

By matrix \([a]\) the priority vector was calculated. The sum of the columns was found
\[ X_j = \sum_{i=1}^{n} a(ij), \]

n of matrix \([a]\) as a row vector \{2.283; 7.500; 9.000; 6.600; 8.866\}
and each element of the column was divided by that sum.

As a result, a new matrix \([a *]\) of values (table 2) was obtained, which allows one to assess the significance of each individual sensory characteristic and, in general, the overall assessment of the perception of sensory characteristics of the semi-finished horse meat product developed by us with the use of a protein fortifier.

Appearance – 1,
Flavor – 4,
Taste – 2,
Texture – 3,
Table 2. Matrix of values of individual indicators in the overall assessment of product perception.

| a(ij)  | Appearance | Flavor | Taste | Texture | Sectional view | Priority vector |
|--------|------------|--------|-------|---------|---------------|----------------|
| Appearance | 0.438 | 0.533 | 0.222 | 0.456 | 0.564 | 0.442 |
| Flavor   | 0.109 | 0.133 | 0.222 | 0.202 | 0.090 | 0.151 |
| Taste    | 0.219 | 0.067 | 0.111 | 0.101 | 0.045 | 0.109 |
| Texture  | 0.146 | 0.1   | 0.167 | 0.152 | 0.188 | 0.150 |
| Sectional view | 0.088 | 0.167 | 0.278 | 0.091 | 0.113 | 0.147 |

This allowed us to obtain a vector-column of priorities when finding the average value of each i-th row.

The results obtained \{0.442; 0.151; 0.109; 0.150; 0.147\}.

Analyzing the results presented in Table 2, within the framework of the distribution of priorities between the indicators of sensory characteristics, the appearance is characterized by the most significant coefficient – 44.2%, then comes the flavor – 15.1%, then the texture – 15.0%, sectional view – 14.7%, taste – 10.9%.

4. Conclusion

When developing the technology of a minced semi-finished product, it is necessary to take into account the opinion of consumers, on the basis of which a qualimetric model of the quality of a product with the best consumer organoleptic properties is subsequently built. The appearance is characterized by the most significant coefficients of organoleptic assessment – 44.2%, and flavor – 15.1%.

The use of mathematical approaches in the processing of expert assessments of the sensory characteristics of semi-finished horse meat product with the use of a protein fortifier gives an objective final result.

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