Using Neural Network Technologies to Assess the Quality Characteristics of Food

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Abstract. A method for assessing the recipe composition of multicomponent food products (for example, meat products) based on the results of studying the chemical and amino acid compositions of final products has been developed. The proposed method is based on the use of artificial intelligence to create a data array using neural networks and the assessment of compositions by cluster analysis of Kohonen networks – to determine the compliance of the recipe composition with the technical documentation indicators.

1. Introduction
Russia’s integration into the world community presupposes developing methods for assessing the quality characteristics of food products. Using various supplements in food products often contributes not only to an improvement in the final product functional indicators, but also to a decrease in their nutritional value. In the pursuit of profit, sometimes there is an abnormal use of various supplements, which has a negative impact on the food quality. Using supplements in an amount which does not meet the requirements of regulatory and technical documentation can lead to gastrointestinal tract disorders, skin diseases, high blood pressure and other pathological changes in a human body [1, 2, 3, 4].

2. Formulation of the problem
Technological processes in the food industry are complex and varied and usually difficult to describe using standard statistical methods.

As an example, let us consider a diagram characterizing the effect of the chemical and amino acid compositions of food formulations (in this case, cooked sausage products) on the final product functional and technological indicators (figure 1).

The presented diagram has been compiled by processing matrix data of factors (formulation components) and input variables (functional indicators) using neural network technologies for creating an array of indicators and multidimensional scaling.
Figure 1. Diagram of neural network approximation of the influence of food products recipe composition on the final product functional indicators.

The current technical documentation for final products usually regulates the chemical composition, organoleptic, microbiological indicators and product yield in relation to the raw materials mass. Nevertheless, it should be mentioned that these indicators do not effectively assess the recipe composition compliance with regulatory requirements.

Each supplement is unique in its chemical and amino acid composition; therefore, the chemical and amino acid composition of the final product will be unique due to the types of raw materials and supplements used (meaning protein supplements). Modern analysis methods and the laboratory equipment used make it possible to quickly and qualitatively determine the chemical and amino acid compositions of raw materials and final products; only a methodology is needed to identify food compositions based on the results of laboratory studies [5, 6, 7, 8].

The aim of the research is to develop a methodology which allows to control the abnormal use of various supplements in food recipes by the chemical and amino acid composition of the final product.

The development of a methodology for assessing the food products recipe composition will protect consumers from the substandard products appearing on the market.

3. Materials and methods

The analysis of the chemical and amino acid compositions of the formulations components has been carried out according to the data given in the references. Cooked sausage products, made in accordance with a plan created according to the principle of Greco-Latin squares, were the objects of the study. The chemical composition of the final products has been determined on a FOSS FoodScan 2 Meat analyzer; a modular KNAUER amino acid analyzer has been used to determine the amino acid composition of the products.

Experiment planning and data processing have been carried out in the STATISTICA v. 13. For creating and processing data arrays the Statistic Neural Networks v.4 e application has been used. Comparison of the formulation composition options has been carried out in the Time Clast application. Each experiment has been carried out in 3–5 repetitions. In case errors and failures were detected, the number of experiment repetitions was increased [9, 10, 11].
4. Results and discussion
As recipe components, we have used trimmed raw meat materials (pork and beef) of all varieties, lard, cheek meat, chicken eggs, beef liver, pork belly and skin, sodium caseinate, soy isolate, gelatin and other components. The research has been carried out at four levels of the Greco-Latin squares plan. A fragment of the factor (formulation components) boundary variations is presented in table 1. For each plan experiment using the Excel application, the chemical and amino acid compositions have been calculated.

Table 1. Fragment of the factor boundary variations.

| No. in sequence | Recipe components            | Values of factors in dimensionless dimension | Indicators in natural values, kg |
|-----------------|------------------------------|---------------------------------------------|--------------------------------|
| 1               | Premium trimmed beef         | 0.0                                         | 33.0                           |
| ...             | ...                          | ...                                         | ...                            |
| 9               | Lard or cheek meat           | 0.0                                         | 13.3                           |
| ...             | ...                          | ...                                         | ...                            |
| 25              | Soy isolate                 | 0.0                                         | 1.0                            |

Based on the results of processing the planning matrix, a neural network in the form of a multilayer perceptron, has been developed and then an array of input variables (it included 17026 recipe options) has been created in order to assess the intermediate variety of composition options. Completing the array functional indicators (chemical and amino acid compositions) has been carried out using a neural network. It should be mentioned that, since the research of meat products is carried out, when analyzing the amino acid composition, it is advisable to determine the oxyproline amino acid, which is a typical representative of connective tissue proteins. A fragment of the data calculation of the chemical and amino acid compositions of the array formulations made by the neural network is given in table 2.

Table 2. Fragment of calculating the chemical and amino acid compositions of the recipe compositions array.

| Recipe composition variants | Solid residual, % | Protein, % on solid residual | Fat, % on solid residual | g/100g protein |
|-----------------------------|-------------------|-------------------------------|--------------------------|---------------|
|                             |                   |                               |                          |               |
|                             |                   |                               |                          | g/100g protein |
|                             |                   |                               |                          |               |
|                             |                   |                               |                          |               |
|                             |                   |                               |                          |               |
| 1                           | 31.2              | 79.5                          | 7.0                      |               |
| ...                         | ...               | ...                           | ...                      |               |
| 897                         | 31.4              | 78.2                          | 7.8                      |               |
| ...                         | ...               | ...                           | ...                      |               |
| 1297                        | 39.3              | 79.0                          | 8.6                      |               |
| ...                         | ...               | ...                           | ...                      |               |
| Sample                      | 22.6              | 78.4                          | 5.1                      |               |
| Standart-                   | 22.5              | 74.9                          | 5.0                      |               |
| Standart                    | 23.7              | 78.8                          | 5.2                      |               |
| Standart+                   | 24.9              | 82.8                          | 5.5                      |               |
To test the efficiency of the neural network, two prototypes of the stolichnaya premium cooked sausage have been made:

1. in accordance with the GOST 23670-2019 recipe;
2. replacing 2 kg of premium beef with soy isolate in the main recipe according to the GOST.

The first sample in the database was designated by the term “sample”, the second corresponded to the position number “58” in the database. The recipe for the stolichnaya premium cooked sausage, considering a ± 5% deviation of each component composition (Standart+ and Standart–), as well as the calculated indicators of a standard sample of the stolichnaya premium cooked sausage (Standart) were simultaneously entered into the array of variables.

A preliminary assessment of the data array on chemical and amino acid compositions has been performed using uncontrolled learning of Kononen maps in the Time Clast application (figure 2, 3). The completeness of the cluster cells (figure 2) characterizes the variants quantitative content in each cluster. Each cluster contains similar options for the recipe compositions. As a result of the cells analysis, it has been found that the Sample, Standart–, Standard and Standart+ samples are in the same no. 7 cluster, which indicates the similarity of the chemical and amino acid and, therefore, the recipe compositions of these variants.

If we change the program task and reduce the number of cluster zones, then we can determine the place of sample no. 58 with replacing 2 kg of premium beef in the main recipe with soy isolate (figure 4).

![Figure 2. Kohonen neural network cluster cells.](image)

![Figure 3. Clustering listing fragment.](image)

![Figure 4. Results of the cluster zones study.](image)
In figure 4, it can be seen that the studied cluster, consisting of 61 recipe variants (y-axis), includes all compositions of interest to us (Sample, Standart-, Standart, Standart+ and sample no. 58), which are located in close proximity to each other.

It is known that the composition of the studied “Sample” sample has been made according to the recipe of the stolichnaya premium cooked sausage, and sample no. 58 with a deviation from the standard. Figure 4 shows that Sample is located between Standart- and Standart+, therefore, it corresponds to the standard recipe. Let us analyze the recipe composition for sample no. 58 (figure 5).

**Figure 5.** Analysis of the recipe composition of the stolichnaya premium cooked sausage with added soy isolate.

The graph (figure 5) shows a peak characterizing the presence of a soy protein preparation in the studied sausage product sample.

Therefore, the use of modern methods and laboratory equipment for the analysis of the chemical and amino acid compositions of food products in combination with Data Mining methods, including planning and neural network processing of the study results, will make it possible to accurately identify the recipe composition of final products.

5. **Conclusion**
1. The use of artificial intelligence to determine the quality characteristics of food has been theoretically substantiated.
2. An array of compositions using the main types of raw materials for sausage production has been developed; chemical and amino acid compositions have been calculated for each variant.
3. Prototypes of premium cooked sausage according to GOST and with replacing with replacing 2 kg of premium beef in the main recipe with soy isolate have been made.
4. The chemical and amino acid composition of the sausage prototypes have been studied.
5. Using artificial intelligence and cluster analysis, identification of sausage prototypes has been carried out.

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