Assessment of the impact of composite mixtures on the quality of new meat products

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Abstract. The object of the study of the present work is to establish the dependence of the ratios of recipe components and the parameters of production of a new type of meat product. The solution of the problem of creating a model formulation of a meat product containing a functional composite mixture with a significant content of dietary fiber is presented. The study was aimed at creating mathematical support, which can be used as a basis in assessing the component composition and parameters of preparing meat semi-finished products with specified structural and technological characteristics. During the work, peculiarities of the process of preparation of meat semi-finished products using a composite mixture of non-traditional vegetable raw materials were revealed. The mathematical model was developed, reflecting dependence of quality indices of finished meat semi-finished products on quantity of composite components in formula and conditions of the preparation process. Optimal dosages of composite mixture and values of preparation parameters are determined. A comprehensive approach was used to study the mechanisms of formation of structural and technological effects in ready-made meat systems under different conditions of their production process. The main result of the work is a model describing nonlinear dependencies of the structural parameters of the meat semi-finished product (moisture binding capacity and moisture retaining capacity), technological indices (mince yield and mince color) on the production process conditions (temperature). The authors have analysed dosages of the components of the composite mixture introduced in order to improve not only the physical properties of the meat product, but also the macro- and micronutrients enriching it.

1. Introduction
The use of low-grade raw materials in the production of meat products, as well as the additional introduction of vegetable additives, affects the quality of the obtained product: its structure is deteriorated and becomes fragmented. The product loses a juicy and gentle structure characteristic of meat products. Therefore, restructuring methods are used in the technology of production of meat semi-finished products. One of them implies inclusion in the formulation of an enzyme preparation based on transglutaminase, the effect of which is aimed at formation of specified rheological indices of quality in the finished product [1, 2].
The aim of the research was to create mathematical support that allows one to model the composition of composite plant mixtures and to select the parameters of meat systems production.

To achieve the objective, a number of objectives were identified. These are investigation of the peculiarities of the process of preparing meat semi-finished products using composite mixtures from non-traditional vegetable raw materials; development of a mathematical model reflecting the dependence of quality indices of finished meat semi-finished products on the amount of composite components in the formula and the conditions of the preparation process. There was also the determination of optimal dosages of composite mixtures and parameters of meat semi-finished products preparation.

Analysis of the meat product formulation process using composite products is presented in the form of functional model IDEF0 (figures 1 - 3) [3, 4].

Figure 1. IDEF0 context diagram

Figure 2. Decomposition diagram «Determination of composite mixture composition and meat product production parameters»
The process of determining the composition for enriching the meat product with macro- and micronutrients consists in the following: in order to calculate the dosage of additionally introduced recipe components, raw materials are necessary from which the products will be produced [5].

A detailed description of the process of determining the composition for fortification of the meat product and its production parameters is given.

Empirically, the laboratory determines the quality indicators of incoming raw materials. Then, the individual components are introduced into the meat product [6]. The technologist compares the quality indicators of all previously obtained mixtures and makes the final decision on the composition of the enriched mixture (figure 3).

**Figure 3. The process of «Selection of components for enrichment of the mixture»**

Composition modeling and selection of parameters for preparing meat semi-finished products is a process of determining optimal dosages of introduced composite mixtures, enzyme preparation under selected production conditions taking into account values of structural parameters of the finished meat product and technological indices [7].

2. Materials and methods
The subject of the study was the meat product production process (TU 9214-023-292405642006). The main recipe components were bio modified udder of cattle, beef liver, second grade beef, raw fat. In addition we brought the composite mix including flour from the germinated beans of chick-pea which are grown up in the Voronezh region (State Standard Specification Russia 8758-76) and a powdery semi-finished product of a girasol (cellulose) (TU 9164-001-312301001-2013) in the ratio 1:1. There was also fermental medicine of a transglyutaminaz (Revada TG 11", the manufacturer (producer): BDF Natural Ingredients, S.L", Spain), dye Active Red (food albumine). Moisture binding capacity (MBC) and moisture retaining capacity (MRC) of the finished meat semi-finished product were determined according to State Standard Specification 53974-2010,Russia; mince yield - according to State Standard Specification 54330-2011,Russia; mince colour - State Standard Specification 13979.9-69,Russia.

Optimal input values were determined by regression factor analysis. The $R^2$ determination factor allows estimating the adequacy of the obtained solution. This factor sets the degree of compliance of the calculated optimal parameters with the actual process conditions.

3. Results
The development of new types of meat products, which include vegetable additives, allows one not only to expand the range of meat products, but also to increase their functionality by increasing the mass share of food fibres. It is necessary to define a dosage of vegetable components in a meat semi-
finished product which was prepared from the biomodified udder of cattle, appointed beef of the second grade, beef liver and fat-raw. Additionally we introduced the plant functional mixture consisting of flour of sprouted mouth seeds and a powdered girasol semi-product. Also we included an enzyme preparation in the formulation, based on transglutaminase, to improve rheological characteristics of meat mince and a dye Active Red to impart consumer qualities to finished products.

The introduction of components of vegetable origin into the composition of meat semi-finished products affects their structural and technological properties: the values of moisture-retaining and moisture-binding capacity, as well as the values of yield and color change.

The degree of influence of the amount of added additives was evaluated by mathematical methods [8, 9]. A complete type $2^4$ factor experiment with star dots was chosen for the study. Recommended dosage values of enzyme preparation, composite plant mixture, dye, as well as one of the parameters of the meat semi-finished product preparation process - temperature - were accepted as values of input factors at the main level [10, 11]. The value of the variation intervals for the input factors was selected taking into account that their increase or decrease by one level would allow one to change the value of the output parameter by an amount not exceeding the measurement error.

Dosages of the enzyme preparation, the composite mixture characterized by a significant amount of dietary fibers and the added dye influence the change of physical properties of the meat semi-finished product - texture, density, cutability and elasticity, which is reflected in the consumer perception of the finished product. Therefore, the moisture-retaining capacity of the meat semi-product, its moisture-binding capacity, as well as yield and chrominance were selected as the output parameters to be analyzed.

We will introduce the symbols for the input factors - $x_1$, $x_3$, $x_4$, - mass fraction,% to the weight of the semi-finished product, enzyme, composite mixture (flour from sprouted nut beans and powdered girasol semi-finished product - 1:1) and the dye Active Red, respectively. $x_2$ - temperature of the semi-finished product in the preparation process, °C. These factors are compatible and non-relatable. Limits of input parameters change are given in table 1.

| Planning conditions | $x_1$ | $x_2$ | $x_3$ | $x_4$ |
|--------------------|-------|-------|-------|-------|
| Main level         | 0.3   | 5     | 7.5   | 0.25  |
| Variation interval | 0.1   | 2     | 1.5   | 0.05  |
| Top level          | 0.4   | 7     | 9.0   | 0.30  |
| Lower level        | 0.2   | 3     | 6.0   | 0.15  |
| Bottom Star Point  | 0.5   | 1     | 4.5   | 0.10  |
| Top star point     | 0.1   | 9     | 10.5  | 0.35  |

The quality indicators of the finished meat semi-finished product are functional dependence of species $Y_i (x_1, x_2, x_3, x_4)$. Structural synthesis of data of model reflecting dependence of moisture-retaining capacity ($Y_1$), moisture-binding capacity ($Y_2$), output ($Y_3$) and chrominance of semi-finished product ($Y_4$) on selected input parameters is required.

A polynomial of the third degree was considered as a mathematical model for assessing the influence of the composition of the composite mixture and the parameters of the meat semi-finished product: $Y_i (x_1, x_2, x_3, x_4)$. Here the degrees of the input parameters satisfy the condition $0 \leq i_1 + i_2 + i_3 + i_4 \leq 3$. $a_k$ - polynomial coefficients are calculated using the least squares method.

The functional dependencies defined were:
The output parameters were then calculated. The calculated values obtained were compared to experimental values. The closest data to experimental data were obtained in all cases using a third degree polynomial.

4. Discussion of the results

According to the obtained dependences, when analyzing the values of the coefficients of the equations, the following conclusions can be drawn. The MBC of the meat semi-finished product is more dependent on the amount of the composite mixture introduced in the first place, then the dosage of the dye and the enzyme preparation follows by the degree of influence. The temperature of the cooking process of meat semi-finished product does not have a significant effect on the indicator of the MBC, because the coefficients of the equation for $x_2$ are slightly lower than for $x_1$, $x_3$, and $x_4$. These input factors have a “positive” effect on the increase in the MBC— an increase in the dosages of the enzyme, dye and composite mixture, as well as in the temperature, the value of the MBC of the meat semi-finished product will increase until it reaches its maximum value.

The change in the MRC value of the meat semi-finished product takes place under the influence of the dosages of the enzyme preparation and dye, as well as in the temperature, which is confirmed by the calculated coefficients of the equations.
by the values of the coefficients found at these polynomial members. If the temperature is increased and the dosage of the enzyme, MRC dye of the meat semi-product is increased, and its yield will decrease. In the analysis of equations (2) and (3), it is noted that changes in $x_1$, $x_3$ values do not significantly affect the MRC value of the meat semi-finished product and its yield.

Analysis of the values of the coefficients of the equation reflecting the dependence of chrominance on the input factors revealed that the output parameter of the $Y_4$, is most influenced by the dosage of the dye and the temperature of the process of preparing the meat semi-finished product. The increase of values of specified input parameters $x_1$ and $x_4$ leads to increase of chrominance values of semi-finished product.

The obtained model (1) - (4) was used to determine optimal dosages of additives, as well as parameters of the technological process of production of combined meat semi-finished products. The optimization task was to find the values $x_1$, $x_2$, $x_3$, $x_4$ at $Y_1, Y_2, Y_3, Y_4 \to \max$. Input parameters varied in the following limits: $x_1 = 0.2 \div 0.4 \%$, $x_2 = 3 \div 7 \ ^\circ C$, $x_3 = 6 \div 9 \%$, $x_4 = 0.15 \div 0.3 \%$.

Conditions for achieving optimal values of structural and technological parameters of finished meat semi-finished product are defined: enzyme dosage - 0.3%, preparation temperature - 5 ° C, mass fraction of introduced composite mixture - 7.5%, and dye Asset Red - 0.25 %. The output factors were as follows: $Y_1 = 82.4 \%$; $Y_2 = 81.3 \%$, $Y_3 = 109.0 \%$ and $Y_4 = 59$ units.

5. Conclusion

The main result of the work is the developed model describing nonlinear dependencies of the structural parameters of the meat semi-product (moisture binding capacity and moisture retaining capacity), technological indices (mince yield and mince color) on the conditions of the production process (temperature) and dosages of the components of the composite mixture. They were introduced in order to improve not only the physical properties of the meat product, but also the macro- and micronutrients enriching it, in particular, the protein fibers. It has been experimentally found that the use of a composite mixture at a dosage of 7.5% allows the production of a gentle and juicy finished meat product of improved consistency. The semi-finished product prepared taking into account optimal dosages of additionally added recipe components and production process parameters was characterized by high density and monolithic properties. The consistency was quite gentle and juicy.

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