FORMALIZATION OF CONCEPTS ABOUT BIOLOGICAL VALUE OF MULTICOMPONENT FOODS WITH INDIVIDUAL DIGESTIBILITY

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The aim of investigations was the substantiation of mathematical methods of calculation of amino-acid composition of multicomponent meat (food) compositions based upon a priori information about digestibility and amino-acid composition of protein of individual recipe ingredients.
The fundamental works in the field of mathematical design of foods, especially their biological value performed by the academician Rogov I.A. and Prof. Lipatov N.N. are connected with formalization of quantitative and qualitative notions about rationality of use of essential amino-acids as contained in the protein of these foods. These scientists in their publications indicate that all the logical constructions, as used for such formalization have been performed under the assumption that the protein of the foods consumed by humans is subjected to complete proteolysis in gastro-intestinal tract.
The ideal character of such notion is corrected with the help of experimental determination or theoretical calculation of digestibility of the protein of the designed foods.
In the present work an attempt has been made to combine the mathematical methods of calculation of amino-acid composition as developed by the academician Rogov I.A., Prof. Lipatov N.N. with participation of Yudina S.B. and digestibility of total protein of multicomponent mixtures.
The logic of such combination is as follows. There is an apriori information about digestibility and amino-acid composition of protein, that is contained in i-th kinds of raw materials, that are used for the production of multicomponent foods.
The dimensionless characteristic (coefficient) of digestibility of the protein of the i-th component according to above authors can be calculated according to the following formula:

$$\pi_i = \frac{P_i}{10 \cdot T_i} \quad , \quad \text{where} \tag{1}$$

T_i - mass fraction of tyrosine in the protein of the i-th component (g of tyrosine/100 g of protein);
10 - dimensionless coefficient of proportionality
The equivalent of digestibility of the total protein of the multicomponent mix can be determined from the following balanced equation:

$$\sum_i X_i \ \pi_i \ p_i = k_p^{\Sigma} \ \sum_i X_i p_i \ , \quad \text{where} \tag{2}$$

x_i - mass fraction of the i-th component in the mixture, fract. unit
p_i - mass fraction of protein in the i-th component, % or fract. unit
k_p^{Σ} - equivalent of digestibility of the total protein of multicomponent mixture, fract. unit

Solving this equation for k_p^{Σ} it is easy to obtain:

$$k_p^{\Sigma} = \frac{\sum_i x_i \pi_i p_i}{\sum_i x_i p_i} \tag{3}$$

The total mass fraction A_j of the j-th amino-acid in the digested protein of the multicomponent mix can be found with the help of the following formula:

$$A_j = \frac{\sum_i x_i \pi_i p_i a_{ij}}{\Sigma \ x_i \pi_i p_i} \quad \text{g/100 g of protein} \quad , \text{where} \tag{4}$$

a_{ij} - mass fraction of the j-th amino acid in the protein of the i-th component, g/100 g of protein.
For the theoretical analysis of conversion of the j-th amino acids in the protein of the multicomponent mixture as a result of its digestion, a modernized version of the formula is of interest (4) :

$$\tilde{A}_j = \frac{\sum_i x_i \pi_i p_i a_{ij}}{\sum_i x_i p_i} \quad \text{g/100 g of protein} \tag{5}$$

numerically characterizing the total mass of the j-th amino acid as contained in the digested protein, related to the initial protein.

Similar to the equivalent of the digestibility of the total protein of the multicomponent mixture, a notion of the "equivalent of digestibility"* of its j-th acid can be introduced:

$$A_j = \frac{\sum_i x_i \pi_i p_i a_{ij}}{\sum_i x_i \pi_i p_i} = k_j^{\Sigma} \cdot \frac{\sum_i x_i p_i a_{ij}}{\sum_i x_i p_i} \qquad (6)$$

where K_j^{Σ} - "the equivalent of digestibility" of the j-th acid, fract. unit.

Elementary algebraic transformations give the following solution of this equation:

$$K_j^{\Sigma} = \frac{\sum_i x_i \pi_i p_i a_{ij}}{\sum_i x_i p_i a_{ij}} \cdot \frac{\sum_i x_i p_i}{\sum_i x_i \pi_i p_i} \qquad (7)$$

Analyzing the formula (7) with the consideration of the formula (3) one can notice that the correlation of the right factors of its denominator and numerator is K_p^{Σ}.

This point makes it possible to propose one more formula for the calculation of the "equivalent of digestibility" of the j-th amino acid:

$$K_j^{\Sigma} = \frac{\sum_i x_i \pi_i p_i a_{ij}}{k_p^{\Sigma} \sum_i x_i p_i a_{ij}}. \qquad (8)$$

The analysis of this formula makes it possible to come to the conclusion that is quite not evident from speculations, that "the equivalent of digestibility" of the j-th amino acid of the total protein of the mix is directly proportional to the linear combination of the coefficients of digestibility of the protein of its individual components and inversely proportional to the equivalent of digestibility of its total protein.

Further developing the idea about the necessity to take into account the individual digestibility of protein of each component of the multicomponent mixture during designing its biological value, step by step realized in mathematical dependences (4-8) the authors offer the

* The authors understand that the notion "digestibility" is not applicable to amino-acids, that in the vital chain of protein digestion are the products of its digestion at the level of membranes and cavities. In this connection, the notion of the "equivalent digestibility" of the j-th amino acid and the corresponding functional indices (7) and (8) characterise, in fractional units, that part of the j-th amino acids as contained in the total protein of multicomponent food mixture, that potentially can be vitally prepared for subsequent digestion by the human organism as a result of protein hydrolysis of its individual components by proteases of gastro-intestinal tract.

following formula for modelling the influence of the ratio of protein-containing components and their digestibility on amino acid composition of the total protein:

$$A_j = \frac{\sum_{i=L+1}^{m} x_i \sum_{1}^{L} x_i \pi_i p_i a_{ij} + \left(\sum_{i=L+1}^{m} x_i - Y \right) \sum_{i=L+1}^{m} x_i \pi_i p_i a_{ij} + Y \sum_{i=L+1}^{m} x_i \sum_{i=m+1}^{n} x_i \pi_i p_i a_{ij}}{\sum_{i=L+1}^{m} x_i \sum_{1}^{L} x_i \pi_i p_i + \left(\sum_{i=L+1}^{m} x_i - Y \right) \sum_{i=L+1}^{m} x_i \pi_i p_i + Y \sum_{i=L+1}^{m} x_i \sum_{i=m+1}^{n} x_i \pi_i p_i}, \qquad (9)$$

where n - total number of ingredients entering the formulation

L - number of ingredients that are not variable during modelling;

m-L - number of ingredients variable (substituted) during modelling

n-m - number of ingredients, being substituting during modelling;

$$\sum_{i=1}^{m} x_i = 1 \; ; \quad \sum_{i=m+1}^{n} x_i = 1$$

$$Y \leq \sum_{i=L+1}^{m} x_i$$

Y - total mass fraction of ingredients in the formulation which are variable during modelling.

The rest of the designations are the same as in the formulae (1-4).

Summarizing the results of the theoretical investigations, as stated in this section one can most surely suppose that they are a methodical base for the determination of promising directions in the field of improving and developing new efficient technologies in the meat industry.

The derived by the authors mathematical dependences are of the kind additive-multiplicative and easily realized with the help of the computers.