# Principles and Methods of Designing a Composition of Meat Products Balanced

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The solution of problems connected with both the creation of new forms of a food and the different aspects of improving agronomic technologies of food cultures, of increasing the productivity of meat and dairy cattle, poultry,etc. cannot be considered as a successful one without the solution of tasks concerning principles and methods of designing a composition of food products nutritionally-balanced.

Long-year investigations carried out in this direction allowed to formulate the following principles of designing a composition of food products nutritionally-balanced and the rations including them: I.A rationally-balanced formulation is corresponded by a rationally-balanced product. 2.In any set of protein-containing ingredients there is such their ratio that provides the amino acid composition which is maximally balanced in relation to statistically based protein standard. 3.The fatty acid composition of a product designed can be purposefully changed by introducing additional fat-containing ingredients. 4.In any set of fat-containing ingredients there is such their ratio at which proportions of saturated, monosaturated and polyunsaturated fatty acids are maximally approached the predetermined ones. 5.While designing a product's formula to be included in the ration, it is necessary to take into account the composition of dishes and products only once-consumed together with a designed one. 6.There is such a composition of a multi-component product which is introduced into once-consumed or daily ration that balances this ration on the energy value, on the ratio of macro- and micronutrients and on the set of food ballast components.

The initial stage of the development of theoretic foundations and concrete methods of realization of designing principles of food products balanced is connected with the formalization of qualitative and quantitative conceptions concerning the rationality of essential amino acids use in the technology of adequate exotrophy.

At the same time it's necessary to emphasize that all the logical conclusions used for such a formalization have been made with the supposition that protein of a product consumed by a man was exposed to complete proteolysis in the digestive tract. However, at present the procedure has been already developed that allowed analytically, on the basis of a priori information, to calculate the proteolysis degree of a protein of multi-component products which are designed on the basis of formalization methods mentioned below.

Formalization, which takes into account the inter-balance of essential amino acids. For realization of such a formalization on the basis of well-known Michell-Block principle the following indices are proposed:

Utilitarity coefficient of the j-th essential amino acid:

$$a_j = \frac{S_{min}}{S_j} \quad , \text{ fraction of unity} \qquad (I)$$

Utilitarity coefficient of the amino acid composition characterizing numerically the essential amino acid balance in reference to the physiologically required norm (standard):

$$U = \frac{\sum_{j=1}^{K} (A_j a_j)}{\sum_{j=1}^{K} A_j} \quad \text{, fraction of unity} \qquad (2)$$

Subject to the equality (I), the formula (2) can be easily re-arranged to the following form:

$$U = \frac{S_{min} \sum_{j=1}^{K} A_{sj}}{\sum_{j=1}^{K} A_j} \quad \text{, fraction of unity} \qquad (3)$$

It is appropriate to mention here that the analogical on writing index, but in another interpretation, was proposed earlier by Brazhnikov A.M., Rogov I.A., Mikhailov N.A.

Index of "compared redundancy" of amino acid content not used for anabolic needs in such a quantity of protein of the product evaluated which is equivalent to utilized content in IOO grams of the standard protein:

$$\sigma_c = \frac{\sum_{j=1}^{K} (A_j - S_{min} A_{sj}}{S_{min}} \qquad (4)$$

In the formula (I-4) the following conventional signs are accepted:

$S_{min}$ - minimum scor of essential amino acids of a protein evaluated with respect to physiologically required norm (standard), % or fraction of unity;

$S_j = \frac{A_j}{A_{sj}}$ - scor of the j-th essential amino acid with respect to physiologically required norm (standard), % or fraction of unity;

$A_j$ - mass quota of the j-th essential amino acid in a product, g/IOO g of protein;

$A_{sj}$ - mass quota of the j-th essential amino acid which corresponds to physiologically required norm (standard), g/IOO g of protein.

The essence of qualitative evaluation of proteins compared by means of indices formalized is that the more values of "$U$" or the lower values of "$\sigma_c$" (ideally $U$ = I; $\sigma_c$ = 0), the better essential amino acids are balanced and the more rational they can be used by the organism.

Formalization which takes into account the ratio of essential and non-essential amino acids. Such formalization allows to evaluate quantitatively the quota of essential amino acids in protein of the concrete product which can be used as precursors of non-essential amino acids biosynthesis or as an energogenic material because of their being unbalanced, shortage or redundancy with respect to non-essential amino acids. Only six mutually exclusive situations can be picked out which reflect proportions of essential and non-essential amino acids in a protein evaluated. In symbol form the conditions corresponding to these situations are described by the following inequalities:

$U = I;\quad \Sigma EAA > \Sigma S;\quad S_j = S_{min} = const > I \qquad (5)$

$U = I;\quad \Sigma EAA \leqslant \Sigma S;\quad S_j = S_{min} = const \leqslant I \qquad (6)$

$U < I;\quad \Sigma EAA > \Sigma S;\quad U \Sigma EAA \geqslant \Sigma S;\quad S_{min} \geqslant I \qquad (7)$

$U < I;\quad \Sigma EAA \geqslant \Sigma S;\quad S_{min} < I;\quad U \Sigma EAA < \Sigma S \qquad (8)$

$I \text{ - } \Sigma EAA \quad (I - \Sigma S) \cdot S_{min} \qquad (8a)$

$I \text{ - } \Sigma EAA \quad (I - \Sigma S) \cdot S_{min} \qquad (8b)$

$U < I;\quad \Sigma EAA < \Sigma S;\quad S_{min} < I \qquad (9)$

In expressions (5-9) the following signs are accepted:

$\Sigma EAA$ - total mass quota of essential amino acids in a protein evaluated, fraction of unity

$U\Sigma EAA$ - mass quota of interbalanced essential amino acids;

$\Sigma S$ - total mass quota of essential amino acids in standard protein, fraction of unity.

For quantitative evaluation of distribution of essential amino acids in the concrete protein which play the role of energogenic material or are precursors of biosynthesis of non-essential ones the following formulas given below were deduced (Table I).

The main criterion of this evaluation,by means of these formulas, of the amino acid composition of a protein of food products or of raw materials for their manufacture from the positions of rational use of essential amino acids is that the product can be considered as a preferable one, when (provided that an organism is equally supplied by anabolic material) a maximum,as compared with other variants, quota of assimilated essential amino acids that its protein contains is able to use for anabolic needs without the degradation on non-essential amino acids biosynthesis and not to use for compensation of energy consumption by the organism because of their interbalance and with non-essential amino acids.

In symbol form this criterion is written as follows:

$$\left\{ R_c \longrightarrow \max; \quad \sum^{BS} EAA \longrightarrow \min; \quad \sum^{EG} EAA \longrightarrow \min \right\} \qquad (I0)$$

The second stage of creating the theoretic and practical foundations of food products designing was the development of modelling methods of influence of the set of formulation ingredients and of their ratio on changes in mass quotas of macro- and micronutrients.

Table I

| Situation corresponding to the inequality | Mass quota of amino acids: which are precursors of biosynthesis of non-essential amino acids | Mass quota of amino acids: which serve as a energogenic material | Coefficient of rationality of the amino acid composition |
|---|---|---|---|
| 5 | $\sum^{BS} EAA = \Sigma EAA - \Sigma S$ | - | $R_c = \frac{U}{S_{min}}$ |
| 6 | - | $\sum^{EG} NEAA = \frac{\Sigma S - \Sigma EAA}{\Sigma S}$ | $R_c = U$ |
| 7 | $\sum^{BS} EAA = \Sigma S(S_{min} - I)$ | - | $R_c = \frac{U}{S_{min}}$ |
| 8 & 8a | - | $\sum^{EG} EAA = (I - U)\Sigma EAA$ | $R_c = U$ |
| 8 & 8b | $\sum^{BS} EAA = (I - U)\,\Sigma EAA - (I - S_{min})$; | $\sum^{EG} EAA = (I - S_{min})$ | $R_c = U$ |
| 9 | - | $\sum^{EG} EAA = (I - U)\Sigma EAA$ | $R_c = U$ |

To become a calculated information of mass quotas of such matters as protein, carbohydrates, fat, minerals, vitamins the following formula may be used which in its essence is the written form of the material balance equation:

$$S_c^{\Sigma} = \frac{\sum_{i=1}^{n} x_i S_i}{\sum_{i=1}^{n} x_i}, \qquad (II)$$

where $S_c^{\Sigma}$ is the mass quota of the concrete macro- or micronutrient in formulating mix, fraction of unity or %; $x_i$ is the mass quota of the i-th component of formulating mix, fraction of unity or %; $S_i$ is the mass quota of the concrete macro- or micronutrient in the i-th component, fraction of unity or %.

This formula can be used also for the calculation of mass quotas of ballast matters.

In case when it is necessary to become an information, e.g., about mass quotas in formulating mix of such matters as amino acids to be a part of protein or as fatty acids to be a part of fat, somewhat another writing form of material balance equation may be proposed:

$$M_j^{\Sigma} = \frac{\sum_{i=1}^{n} x_i S_i M_{ij}}{\sum_{i=1}^{n} x_i S_i} \qquad (I2)$$

where $M_j^{\Sigma}$ is the mass quota of the j-th component of a complex macronutrient in multi-component formulation, fraction of unity (or %, or g/IOO g of complex macronutrient); $M_{ij}$ is the mass quota of j-th component in the concrete complex macronutrient of the i-th component of the formulation, fraction of unity (or %, or g/IOO g of complex macronutrient).

On the basis of this equation at the limitations below-mentioned the authors proposed the following algebraical expression that is a fundamental one for modelling protein amino acid composition in multi-component formulating mixtures:

$$A_j = \frac{\sum_{i=l+1}^{m} x_i \sum_{i=1}^{l} x_i p_i a_{ij} + \left(\sum_{i=l+1}^{m} x_i - Y\right) \sum_{i=l+1}^{m} x_i p_i a_{ij} + Y \sum_{i=l+1}^{m} x_i \sum_{i=m+1}^{n} x_i p_i a_{ij}}{\sum_{i=l+1}^{m} x_i \sum_{i=1}^{l} x_i p_i + \left(\sum_{i=l+1}^{m} x_i - Y\right) \sum_{i=l+1}^{m} x_i p_i + Y \sum_{i=l+1}^{m} x_i \sum_{i=m+1}^{n} x_i p_i} \qquad (I3)$$

where $n$ is the total number of ingredients to be a part of the formulation; $l$ is the number of ingredients not to vary while modelling; $(m - l)$ is the number of ingredients to vary while modelling; $(n - m)$ is the number of ingredients which are substituted while modelling; $\sum_{i=1}^{m} x_i = I$; $\sum_{i=m+1}^{n} x_i = I$; $Y \leqslant \sum_{i=1}^{m} x_i$ is the total mass quota of ingredients in the formulation which vary while modelling; $x_i$ is the mass quota of the i-th ingredient in the formulation, fraction of unity; $p_i$ is the protein mass quota in the i-th ingredient, %; $a_{ij}$ is the mass quota in the protein of i-th ingredient of the j-th amino acid, g/IOO g of protein, and $A_j$ is the mass quota of the j-th amino acid in the protein of the formulation being modelled, g/IOO g of protein.

The analysis of existing formulations and of real possibilities of meat and dairy plants showed that while developing new forms of products, including products for special use, it is doubtful whether it should be used in their formulations more than six protein-containing ingredients. In this connection, it is simple to deduce the dependence on the basis of the total equation (I3) which allows by means of computer to realize the cyclic algorithm of modelling the amino acid composition of six-component formulation. It looks like as follows:

$$A_j = \frac{x_1^{R_1}(p_1 a_{1j} + p_2 a_{2j}) + p_2 a_{2j} + R_2\{R_3[R_4 p_3 a_{3j} + (1-R_4) p_4 a_{4j}] + (1-R_3)[R_5 p_5 a_{5j} - (1-R_5) p_6 a_{6j}] - p_2 a_{2j}\}}{x_1^{R_1}(p_1 - p_2) + p_2 + R_2\{R_3[R_4 p_3 + (1-R_4) p_4] + (1-R_3)[R_5 p_5 - (1-R_5) p_6] - p_2\}} \qquad (I4)$$

Original essence of this model consists in that while its realizing with computer it is quite enough to be given to only the mass quota of the first component. After that values of $x_I^{R_I}$, $R_2$, $R_3$, $R_4$ and $R_5$ are chosen on the modelling results which to the greatest degree satisfy the rationality criterion (I0), the following values are calculated on the next formulas: $x_2 = I - x_I^{R_I} R_2$; $x_3 = R_2 R_3 R_4$; $x_4 = R_2 R_3 (I - R_4)$; $x_5 = R_2(I - R_3)R_5$;

$$x_6 = R_2(I - R_3)(I - R_5). \qquad (I5)$$

For all this the following limitations must be maintained:

$$R_2 \leq (I - x_I) \qquad R_3 \in [0;I] \qquad R_4 \in [0;I] \qquad R_5 \in [0;I] \qquad (I6)$$

While introducing other limitations on the model corresponding to any intermediate situation, including five-, four-, three- and two-component systems, can be obtained.

Procedure of designing formulations of multi-component food products includes three stages. In the first of them by means of formulas (I4) and (I5) modelling the protein amino acid composition of a food product designed is realized and those values are chosen which to the greatest degree satisfy the criterion (I0). In the second stage the evaluation of the fatty acid composition of a product designed takes place. For this purpose the following formula is used:

$$l_j^{\Sigma} = \frac{\sum_{j=1}^{5} \sum_{i=1}^{r} x_i^L L_i l_{ij}}{\sum_{i=1}^{r} x_i^L L_i} \qquad (I7)$$

where $l_{ij}$ is the mass quota of the j-th fatty acids in the fat of the i-th component, %; $l_j^{\Sigma}$ is the mass quota of the j-th fatty acids in the fat of multi-component food products, % to fat; $L_i$ is tha mass quota of fat in the i-th component, %; $x_i^L$ is the mass quota of the i-th fat-containing component in a food product designed, fraction of unity.

Values of index j in the formula (I7) are identified, respectively, with: I - monounsaturated fatty acids; 2 - saturated fatty acids; 3 - linoleic acid; 4 - linolenic acid; 5 - arachidonic acid. In this case it's taking into account that mass quotas $x_i^{L(p)}$ of components containing protein besides fat are constant as pre-determined by the first stage of designing. On the results of this evaluation such mass quotas $x_i^L$ are chosen which in total with $x_i^{L(p)}$ provide the required approximation to physiologically necessary ratio between saturated, mono- and polyunsaturated fatty acids.

In the third stage the energy value of food products designed is calculated. For this purpose the following formula is used:

$$Q = 17{,}2 \sum_{i=1}^{n} x_i^p P_i \{1 - S_{mm}(x_i^p)\} + 0{,}388 \sum_{j=1}^{2} \sum_{i=1}^{r} x_i^L L_i l_{ij} + 15{,}7 \sum_{j=1}^{3} \sum_{i=1}^{s} x_i^s S_{ij} \qquad (I8)$$

where $x_i^s$ is the mass quota of the i-th carbohydrate-containing component, fraction of unity; $s_{ij}$ is the mass quota of the j-th sugars in the i-th carbohydrate-containing component, %; I7,2; I5,7; 0,338 are coefficients proportionate to the energy value of proteins, carbohydrates $(kJ(\%\cdot g)^{-I})$ and fats $(kJ(\%\cdot\%\cdot g)^{-I})$.

The first sum in the second item of the formula (I8) takes into account the fact that at correct balance of the fatty acid composition polyunsaturated acids have not to be used for compensation of energy consumption by the organism.

In the first sum of the third item of this formula values of index j are identified with: I - monosaccharides; 2 - disaccharides; 3 - polysaccharides hydrolyzed.

After that the energy value was calculated by means of the formula (I8), it is compared with the required value of $Q_s$. If the energy value calculated is found to be less than $Q_s$, additional technologically permissible carbohydrate-containing components are introduced into the product composition. If the calculated value of $Q$ is found to be more than $Q_s$, $I_i$ with excessively high values of $L_i$ may be changed by new ones (technologically permissible) with lower values of $L_i$.

The procedure of designing a composition above-described can be used for grounding food rations balanced including the first and the second dishes and allows to take into account the composition of garnishes, bread quantity consumed, desserts and drinks.