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DETERMINISTIC APPROACHES TO DESIGNING BIOLOGICAL AND ENERGY VALUES OF MEAT PRODUCTS AND RATIONS CONTAINING THEM

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SUMMARY

This report deals with the methodology of designing multi-component food products being characterized by the complex of nutritional value parameters required. Principles and criteria for assessing the rationality of use of protein- and fat-containing raw material, namely its essential amino acids and polyunsaturated fat acids were formulated on the base of formalization of biochemistry, physiology and nutrition hygiene conceptions.

Methodological approaches cited in the report served as a base for developing the technique of grounding proportions of food products or their rations ingredients which satisfy the deterministic complex of requirements concerning biological and energy values and which provide the rational use of essential food substances.

On a wide circle of approaches and questions considered this report serves as a stating one and may be of interest for scientific workers studying problems of technology improvement and development of new types of food products.

INTRODUCTION

The problem of designing food products with a required complex of consumer properties was formulated as a new independent development in science quite recently. The first publications on this problem were widely discussed on pages of journal "Meat Industry of the USSR". Taking into account those different opinions expressed during discussion and following the new paradigm of adequate exotrophy, it is quite correct to divide consumer properties into two main groups - those depending on the composition and those depending on the structure. Such dividing doesn't contradict to the following determination of the most capacious component of consumer properties of food products - their nutritional value.

MATERIALS AND METHODS

Deterministic approaches to designing biological and energy values of meat products and containing them rations allow to specify considerably existing models of these components of nutritional value. Let's begin this chain with a model of energy value of a food product designed. At the first approximation, proceeding from wide-spread conceptions that energy value of a food product is predetermined by proteins, fats and carbohydrates it contains which take part in the biological oxidation process and give off on average 38,8 kJ of energy per I g of fat, I7,2 kJ per I g of protein and I5,7 kJ per I g of carbohydrates, it is rather easy to derive a dependence connecting mass fractions of these components with an assimilated energy Q per IOO g of mass which is a mathematical model of energy value of a food product designed:

$$Q = 17{,}2\ P + 38{,}8\ L + 15{,}7\ C, \quad \text{kJ/100 g}, \qquad (I)$$

where P,L,C are mass fractions of protein, fat and carbohydrates, respectively, %; I7,2; 38,8; I5,7 coefficients, $\text{kJ}\cdot(\%\cdot\text{g})^{-1}$.

Furthermore, taking into account a conception supported by authors of this report which is oriented on the maximum complete use of protein for anabolic purposes of an organism it should be to correct the model of energy value of a food product designed in such a manner that the required value of Q would be ensured by its fat and carbohydrate components. Protein share must be limited by only that its assimilated part which cannot be used for anabolic purposes. For realization of such a correction let's formulate two postulates which do not contradict to well-known definitions.

The first postulate consists in that for anabolic purposes from the whole mass of assimilated amino acids only that their quantity may be used which is proportional to the use of essential amino acids.

The second postulate proposes that from the whole mass of assimilated essential amino acids for anabolic purposes of a consumer organism such their quantity may be used which is predetermined by their balance in relation to statistically based standard taking into account a physiological specificity of a concrete group to which refers a consumer supposed.

The first and the second postulates allow to speak out a number of considerations being rather important for designing rational amino acid composition of protein.

Let's examine such a case when protein of a food product designed, in reference to statistically based standard, contains if only one essential amino acid in smaller quantity than it itself.

It is not difficult to show that summary mass fraction of assimilated essential amino acids, which are capable to be used by an organism for anabolic purposes without the following degradation, may be determined by formula:

$$A_u^{\Sigma} = \sum_{j=1}^{k} A_j a_j \qquad (2)$$

where A_j is a mass fraction of the j - th essential amino acid in protein of a food product designed, g/IOO g protein;

$a_j = \frac{C_{min}}{C_j}$ is an utilitarity of the j - th essential amino acid, unit fraction; C_j is a score of the j - th essential amino acid in reference to its mass fraction in standard selected, unit fraction; $C_{min} = \min C_j$ is a minimum from scores of essential amino acids of protein of a product designed in reference to standard selected, unit fraction.

Rest essential amino acids can be used by an organism either as precursors of biosynthesis of non-essential ones, or as an energenic material. Their distribution on these roles depends on predetermined by physiological features and taken into account by selected as a standard protein relation between sums of essential and non-essential amino acids which is characterized by the mass fraction $A_{\text{э}}^{\Sigma}$ of essential amino acids in it expressed in grams per I00 g protein. If a numerical value of expressed in per cent fraction A_{a}^{Σ} in their sum with non-essential amino acids is less or equal to a numerical value of $A_{\text{э}}^{\Sigma}$, that is

$$|a^{\Sigma}| = \left|\frac{100 A_{a}^{\Sigma}}{A_{a}^{\Sigma} + 100 - A_{\varphi}^{\Sigma}}\right| \leq |A_{\varphi}^{\Sigma}| \qquad (3)$$

there is no need for an organism to use a difference between the actual sum A_{φ}^{Σ} of assimilated essential amino acids and A_{a}^{Σ} for biosynthesis of non-essential ones, and this difference can serve as an energenic material for the compensation of its energy consumption.

On the basis of the second postulate it is not difficult to show that for anabolic purposes of an organism from the whole quantity of assimilated protein P_y would be used that part which is directly proportional to A_{a}^{Σ} and inversely proportional to A_{φ}^{Σ} calculated from the formula:

$$P_a = P_y \frac{A_a^{\Sigma}}{A_{\varphi}^{\Sigma}} \qquad (4)$$

which is easily converted into the following form subject to (2):

$$P_a = P_y \cdot C_{min} \qquad (5)$$

The same quantity of assimilated protein will be used by an organism for anabolic purposes in case when $|a^{\Sigma}| > |a_{\varphi}^{\Sigma}|$. However, a part of A_{φ}^{Σ} will be required to an organism as precursors for synthesis of their deficit essential amino acids.

In both cases the quantity $P_{\text{э}r}$ of assimilated protein which may be used by an organism for energy purposes represents a difference between P_y and P_a :

$$P_{\text{э}r} = P_y (1 - C_{min}) \qquad (6)$$

Let's consider the case when assimilated protein of a food product designed contains all the essential amino acids in quantities much higher than standard selected. In such situation all assimilated essential amino acids may be used by an organism as a anabolic material. However, to consider this situation as a variant of the rational use of essential amino acids is impossible. Although they would not serve in this case as an energenic material; degradation products of their quite definite part $A_{\delta c}^{\Sigma}$ must serve as precursors of biosynthesis of essential amino acids

$$A_{\delta c}^{\Sigma} = A_{\varphi}^{\Sigma} - A_{\text{э}}^{\Sigma} \qquad (7)$$

The reasonings just cited allow to formulate the main principle and criterium for designing amino acid composition of protein of new varieties of food products from a position of the rational use of essential amino acids consisting in that technologically approved set and mass fractions X_i^P of protein-containing components it contains may be considered as preferable, when, provided that an organism is uniformly supplied by anabolic material, a maximal fraction (as compared with other variants) of assimilated essential amino acids, the protein contains, is capable to be used for anabolic purposes without a degradation of non-essential amino acids for biosynthesis needs, and, all the more, without a biological oxidation for the compensation of organism's energy consumption.

Subject to that while designing it is possible to achieve such variants when $C_{min} \geq 1$, as well variants when $C_{min} < 1$, a criterion of choice X_i^P corresponding to this principle may be written in symbolic form as

$$A_{\varphi}^{\Sigma}(X_i^P) - A_{\text{э}i}^{\Sigma}\left\{\frac{A_{\varphi}^{\Sigma}(X_i^P) - A_a^{\Sigma}(X_i^P)}{C_{min}(X_i^P)}\right\} \to min \qquad (8)$$

Let P_i denote a mass fraction of assimilated protein (expressed in %) in i-th protein-containing component and Q_{ij} denote a mass fraction (expressed in grams per I00 g of protein) of the j-th essential amino acid in protein of the i-th component. In this case a criterion (8) of searching for a preferable relation between mass fractions X_i^P of these components in a food product designed from a position of the rational use of k essential amino acids, they contain, may be written down in the following form:

$$\left\{\sum_{j=1}^{k}\frac{\sum_{i=1}^{n} X_i^P P_i Q_{ij}}{\sum_{i=1}^{n} X_i^P P_i} - \sum_{j=1}^{k} A_{\text{э}j};\ \frac{\sum_{j=1}^{k}\frac{\sum_{i=1}^{n} X_i^P P_i Q_{ij}}{\sum_{i=1}^{n} X_i^P P_i} - C_{min}(X_i^P)\sum_{j=1}^{k} A_{\text{э}j}}{C_{min}(X_i^P j)}\right\} \to min \qquad (9)$$

where $\left\{\sum_{j=1}^{k}\frac{\sum_{i=1}^{n} X_i^P P_i Q_{ij}}{\sum_{i=1}^{n} X_i^P P_i}\right.$ is a mass fraction of the j-th essential amino acid in protein of a food product designed at fixed j, g/I00 g protein;

$A_{\text{э}j}$ is a standard mass fraction of the -th essential amino acid, g/I00 g protein.

Here, it is appropriately to emphasize that a symbolic representation of a criterion (9) doesn't involve satisfying a limitation that $\sum_{i=1}^{n} X_i^P = I$, as the sum of protein-, fat- and carbohydrate-containing components of a food product designed must be equal to 1, but not the sum of protein-containing components of such a food product. It is not excludable at that some components can contain simultaneously two or three macronutrients.

Symbols above-used allow to re-arrange an equality (6) into the next form:

$$P_{\text{э}r} = \sum_{i=1}^{n} X_i^P P_i \left\{1 - C_{min}(X_i^P)\right\} \qquad (I0)$$

After the choice of X_i^P, which satisfy a criterion (9), it should not forget that an equality (I0) is correct only for the case, when $C_{min}(X_i^P) \leqslant I$. In opposite case $P_{\text{э}r} = 0$ as it was shown above.

Correcting the formula (I) in regarding to contribution of fat components of a food product designed into its energy value, it is necessary to state briefly the most common point of view concerning their physiological purposes.

Data presented in the special literature and regarding the biological role of a fat consumed with a food show that the most effective action for an organism is achieved in that case when proportions of saturated, monounsaturated and polyunsaturated fat acids, which are necessary from a physiological position for an individual consumer or for the groups of consumers united on the definite criteria, are observed. As an example, the following proportions for a mean-statistical consumer, presented in a special literature, may serve - 0,3 : 0,6 : 0,I.

It was shown that polyunsaturated fat acids belonged to essential substances which are not synthesized in an organism from saturated and monounsaturated fat acids or other organic substances; the main types of polyunsaturated fat acids consumed by an organism with a food are linoleic, linolenic and arachidonic acids. Their biological role in an organism is highly important and various, however, the most important property of these substances is concluded in that they take part in forming structure elements as compulsory components. It allows to refer polyunsaturated fat acids to plastic substances used for anabolic purposes of an organism.

The reasonings above-cited reduce themselves to that it should not take into account polyunsaturated fat acids content while determining energy value of a correctly balanced on proportions of fat acids food product designed which is necessary for the compensation of share of physiologically stipulated energy consumption by an organism predetermined by this product's quantity in each single-consumed food ration.

A mathematic representation of a model with help of which it may be evaluated the effect of mass fractions used of fat-containing components in formulation of a food product designed on the balance of saturated, monounsaturated and polyunsaturated fat acids, has the following form:

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

where l_j^{Σ} is a mass fraction of j-th fat acids in a fat of multi-component food product, %; l_{ij} is a mass fraction of the j-th fat acids in a fat of the i-th component,%; L_i is a mass fraction of fat in the i-th component,%; x_i^L is a mass fraction of the i-th fat-containing component in a food product designed, unit fraction.

Index values in the formula (II) are identified,respectively: I - with monounsaturated fat acids; 2 - with saturated fat acids; 3 - with linoleic acid; 4 - with linolenic acid; 5 - with arachidonic acid.

As a final step of model correcting (I) serves analysis of carbohydrate-containing components contribution to the energy value of a food product designed. Taking into account that the main duty of carbohydrates in man's nutrition is energenity it is necessary to discover a mass share of polysacharides in them which are not hydrolyzed in digestive tract, that is, they are not an energy source.

Model for evaluating the effect of carbohydrate-containing components on changes in the composition of a food product designed of mass shares of hydrolyzed and non-hydrolyzed carbohydrates has the following form:

$$C_j^{\Sigma} = \sum_{j=1}^{4}\sum_{i=1}^{3} x_i^C C_{ij} \qquad (I2)$$

where C_j^{Σ} is a mass fraction of the j-th carbohydrates in multi-component food product, %; C_{ij} is a mass fraction of j-th carbohydrates in the i-th carbohydrate-containing component, %; x_i^C is a mass fraction of i-th carbohydrate-containing component in a food product designed, unit fractions.

Index j values in the formula (I2) are identified, respectively: I - with monosaccharides; 2 - with disaccharides; 3 - with hydrolysing polysaccharides; 4 - with non-hydrolysing polysaccharides.

The reasonings above-cited concerning the influence of amino acid-, fat acid- and carbohydrate-composition of assimilated macronutrients of a food product designed on their contribution into its energy value allow to perform the model (I) of this important quality index in the following form subject to all the limitations assumed in this article:

$$Q = 17{,}2\sum_{i=1}^{n} x_i^P P_i\{1 - C_{min}(x_i^P)\} + 38{,}8\sum_{j=1}^{2}\sum_{i=1}^{\ell} x_i^L l_{ij} + 15{,}7\sum_{j=1}^{3} \sum_{i=1}^{3} x_i^C = C_{ij} \qquad (I3)$$

RESULTS AND DISCUSSION

Presented in this article deterministic approaches to designing food products with the required complex of food value parameters allow to propose the following sequence of designing a composition adequate on macronutrients which ensures the rational use of raw material, being a source of essential amino acids, a high biological value of protein, maximum approximating to physiologically stated proportions of saturated, mono- and polyunsaturated fat acids and pre-determined energy value.

In the first stage, by means of the dependence entering into the mathematical recording of criterion (9), modelling an amino acid composition of protein of a food product designed is carried out and x_i^P ensuring min of the functional (9) are selected:

$$A_j = \sum_{j=1}^{K}\sum_{i=1}^{n} x_i^P P_i a_{ij} \Big/ \sum_{i=1}^{n} x_i^P P_i$$

In the second stage, by means of the equation (II) modelling a fat acid composition is realized taking into account that mass fractions of components $x_i^{L(p)}$ containing protein apart from fat are constant as it is predetermined by the first stage of designing. On the basis of modelling results such mass fractions of x_i^L are selected which ensure together with $x_i^{L(p)}$ the required approximation to physiologically necessary proportions of saturated, mono- and polyunsaturated fat acids.

In the third stage, from the formula (I3) an energy value Q of a food product designed is calculated, but in its third component only those $x_i^{C(p,L)}$ are taken into account which serve as sources of protein and/or fat. Afterwards, the result achieved is compared with the required value of Q. If a calculated energy value is less than Q, additional (technologically approved for foods) carbohydrate-containing components are introduced into product's formulation in such quantities which ensure the required value of Q subject to (I3). If Q_p is more than Q, in this case x_i^L are recalculated. If necessary, x_i^L with too high values of L_i may be replaced by new, technologically approved ones with smaller values of Δ_i .

The given sequence of composition designing may be used as a base for balanced food rations including the first and the second dishes and allows to take into account the garnish composition, bread quantity consumed, desserts and beverages. It should not forget that calculated balanced amino acid composition of multi-component system may be achieved only in that case when these components are simultaneously consumed.

Deterministic approaches to designing multicomponent food products allowed to develop the principles, criteria and sequence for basing proportions of protein-, fat- and carbohydrate-containing ingredients, which ensure satisfying the complex of requirements corcerning biological and energy values provided that essential substances are rationally used. The sequence proposed and criteria for basing the composition may be applied for designing food rations.