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Original scientific paper

BALANCE PROTEIN SUPPLEMENTS ON THE CRITERION OF CONVERTIBLE PROTEIN

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ABSTRACT:
The main sources of vegetable protein are seeds of legumes and oilseeds, which differ as by total content as by the quality. One of the least expensive and most rapid method of assessing the quality of protein is a chemical method, based on a comparative analysis of its amino acid composition, in particular, essential amino acids (EAA), and "ideal" protein. A widespread indicator of the proximity of the protein to the ideal is the minimum period, which shows how much of it can be used by the body for plastic needs (the main exchange and ensuring of body weight gain). Obviously, the more of this (convertible) protein in the product, the better (but not more than the daily value). One of the methods of obtaining a grain product with an increased convertible protein is blending, i.e. mixing in a certain proportion of different types of protein raw materials. In this case, the content of the converted mixture may be greater than in the components, and the excess - less. The article presents a methodology for calculating the proportion of convertible protein in the product, as well as a new approach to the formation of effective mixtures. On the basis of this method, the results of the calculation of such mixtures on the example of a grain product with the use of collapsed white lupine, linseed cake and ginger seeds as components are shown. In all cases, there are rational proportions of the mixture, in which its convertible protein exceeds this figure in the component. The accuracy of the calculations largely depends on the accuracy of the total protein content and EAA.

1. Introduction

In the process of nutritional (food) chain is lost 60-75 % of the protein in the undigested remnants of food, not recycled in the body amino acids, excreted in the urine in the form of a collapse in the exchange processes (motion, updating the proteins of the tissues, etc.) and through the skin and skin and hair covers [1]. Especially large losses of proteins occur due to the cost of their biosynthesis, as animal proteins are significantly different in amino acid composition from plant proteins. The lack of human and animal ability to synthesize a number of amino acids leads to the fact that their needs in the latter they satisfy due to the increased amount of plant proteins. The body can synthesize a number of missing amino acids, but only to the detriment of the hormonal and enzymatic systems. Hence, a balanced protein diet is relevant in order to increase the efficiency of its utilization by the body.

As protein supplements in the diet uses a fairly extensive range of protein-containing products of plant origin, which differ not only in quantitative but also qualitative composition of the protein.

One of the advantages of protein-containing products of plant origin is the presence of dietary fibers in their composition. According to the theory of adequate nutrition [2,3] dietary fibers, without splitting under the action of enzymes of the gastrointestinal tract to monomers and without participating in metabolism, perform important physiological functions in the digestion processes. The presence of dietary fiber in the human food product allows to maintain the enzyme, bacterial, immune and other systems of the body. The absence of these components of nutrition violates natural technology processes assimilation food in the gastrointestinal tract, that, in turn, with the passage of time leads to emergence of various pathologies.

There are various methods for assessing the nutritional quality of protein. For example, to justify the daily intake of dietary protein in the United States used its efficiency coefficient – Protein efficiency ratio (PER), determined by the impact of a particular protein on muscle building. According to these recommendations, a person should consume proteins with PER better than casein PER, and at lower PER values of the tested protein, its amount should be increased. Net utilization of NPU (net protein utiliseichen) depends on the combination of amino acids in the protein and their digestibility [4].

The evaluations of the quality of the protein by chemical methods are less expensive and more operational, based on a comparative analysis of its amino acid composition and the "ideal" protein.

To assess the adequacy of the amino acid composition of proteins, it is recommended to compare their amount with the composition and amount of amino acids in the reference ("ideal") protein - a model with pure utilization equal to 100 %. In practice, the reference protein used pure casein, the protein of whole chicken protein, soya protein or the protein of breast milk.

The paper [5,6] considers a number of indicators that assess the proximity of this protein to the "ideal". The physiological meaning has only a minimum speed C_m .

$$C_m = min\{C_i\}, i = \overline{0,n},$$

where

$$C_i = b_i / a_i$$

a_0, b_0 – the total content of interchangeable amino acids (IAA) in the "ideal" and considered protein, %;

a_i, b_i – the content of essential amino acids (EAA) in the "ideal" and considered a protein, %;

n – number of EAA under consideration.

For «ideal» protein $C_0=C_1=\ldots=C_i=\ldots= C_n=1$, for «good» $C_1=\ldots=C_i=\ldots= C_n$, but $C_0 \neq C_i$. Defective protein has $C_m=0$. Should note, that

$$a_s = \sum_{i=0}^{n} a_i = 100 \quad и \quad b_s = \sum_{i=0}^{n} b_i = 100.$$

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Utilization of protein by the animal body is realized in two directions:

• For plastic needs, the protein is absorbed in certain proportions of amino acids corresponding to the proportions in the ideal protein. Let's call this part a convertible protein.

• The remainder of the convertible part of the protein (excess protein) is spent on energy needs. However, it should be keep in mind that the absorption of protein is spent 4 times more energy than the absorption of starch.

When protein intake exceeds the body's physiological need for amino acids, their (amino acids) excess is utilized in three main ways [7]:

1. Mainly due to the increased production of urea, which is associated with the need to remove the processes of decomposition of ammonia formed during the oxidation of proteins.

2. Intensification of oxidation, with the formation ultimately of CO_2 and ammonia

3. Formation of glucose (neoglucogenesis).

Grain products may contain protein with various combinations of amino acids and, in particular, limiting. When mixed, their value changes. It can be assumed (hypothesize) that the grain product, consisting of two or more components, in some cases contains a higher value of the converted protein than the original ingredients (components).

The purpose of this article is to show the methodology for calculating the proportion of convertible protein in the product, as well as a possible approach to the formation of effective mixtures.

2.Materials and methods

On the basis of long-term biomedical research FAO/WHO proposed a criteria for determining the quality of protein – a standard balanced by essential amino acids (Table 1) and best meets the needs of the body [8,9,10,11,12,13].

Table 1.

Amino acid composition of the "ideal" protein

Amino acids Essential amino acids (EAA), g/100 g protein	Standard FAO (1973)	Standard FAO (1974)	Standard FAO/WHO for children 2-5 years
Lysine	5.5	5.1	5.8
Methionine+ Cystine	3.5	2.6	2.5
Isoleucine	4.0	4.2	2.8
Leucine	7.0	7.0	6.6
Threonine	4.0	3.5	3.4
Phenylalanine+ Tyrosine	6.0	7.3	6.3
Tryptophan	1.0	1.1	1.1
Valine	5.0	4.8	3.5

Note that the "ideal" protein contains not only essential amino acids (EAA) in certain proportions, but also a certain proportion of interchangeable amino acids (IAA).

For the calculation and assessment of the biological value of protein mixtures was adopted amino acid composition of white lupine varieties «Degas», of Camelina seeds variety «Panzyak» and, for comparison, linseed cake (Table 2).

Based on the data in Table 1 and Table 2 the calculation of the scores was made. The calculation results are presented in Table 3.

In Table 3 is shown skor protein seeds of Camelina, lupine collapsed and linseed cake for some species of farm animals, fish and humans.

Table 2.

Amino acid composition of protein of white Lupin milled grade «Degas», seeds Camelina varieties «Panzyak» and linseed cake (% relative to protein)

Indicators	The white lupine varieties «Degas» milled	Camelina seeds [14]	Soybean meal
The content of total protein, %	40.36	27.04	30.9
Lysine	4.62	4.62	3.7
Methionine+ Cystine	2.11	5.14	3.7
Isoleucine	4.12	2.77	4.0
Leucine	6.97	5.88	5.9
Threonine	3.57	4.14	3.6
Phenylalanine+ Tyrosine	8.81	7.17	7.1
Tryptophan	0.74	0.81	1.6
Valin	3.74	4.14	4.9

Table 3.

The protein scor of lupine white collapsed varieties "Degas", seeds of Camelina varieties "Panzyak" and linseed cake for humans

Indicators	Camelina	Lupine collapsed	Linseed cake
Lysine	0.84	0.84	0.67
Methionine+ Cystine	1.47	0.60	1.06
Isoleucine	0.69	1.03	1.00
Leucine	0.84	1.00	0.84
Threonine	1.04	0.89	0.90
Phenylalanine+ Tyrosine	1.20	1.47	1.18
Tryptophan	0.81	0.74	1.60
Valine	0.83	0.75	0.98

3. Results and Discussions

One of the methods of obtaining a grain product with an increased convertible protein is blending, i.e. mixing in a certain proportion of different types of protein raw materials. The algorithm for calculating the proportion of converted protein in the mixture can be represented as follows:

1. The values of the total protein B1 and scor of its EAA $\{C_{1i},\ i=\overline{1,n}\}$ for the first component of the mixture are given;

2. Values of total protein B2 and scor of its EAA $\{C_{2i},\ i=\overline{1,n}\}$ for the second components of the mixture;

3. The value of the fraction of the first component X;

4. The total protein of the mixture is calculated by the formula B=X(B_1-B_2)+B_2;

5. Calculate the EAA skors of the protein mixture $\{C_i,\ i=\overline{1,n}\}$ by the formula

$$C_i = \frac{X\left(C_{1i}B_1 - C_{2i}B_2\right) + C_{2i}B_{2i}}{X\left(B_1 - B_2\right) + B_2}$$

The minimum scor of the mixture $C_{min} = min\{C_i,\ i=\overline{1,n}\}$ and the corresponding amino acid is determined;

7. Calculation of the percentage conversion of protein in a mixture of $K(X) = C_{min}B$;

8. By varying the variable X find the maximum value

$$K(X)_{max} = max\{K(X)\}$$

On the basis of the proposed models and step-by-step calculation algorithm, it is not difficult to create a computer programm particular language, including the algorithm to find the maximum or use a simple search X.

To estimate the proportions and the converted protein of the mixture of the two components, the following initial data are taken:

- B_1 и B_2 – the protein content in each component
- C_{i1min} и C_{i2} – minimum emergency first protein components and soon the corresponding EAA in the second component,
- C_{j2min} и C_{j1} the minimal protein components of the second ambulance and an ambulance of the corresponding EAA in the first component.

Denote the proportion of the first component of the mixture X.

The protein content in the mixture

$$B_S = (B_1 - B_2)X + B_2;\ 0 < X < 1 \quad (1)$$

The scor of «k» EAA is depending on the proportion of first component in the mixture

$$C_{kS} = (B_1C_{k1} - B_2C_{k2})X + B_2C_{k2};\ 0 < X < 1 \quad (2)$$

Choose the proportions of the mixture so that the converted proteins in the mixture calculated by the limiting EAA of the first and second components are equal, i.e.

$$B_1C_{i1min}X + B_2C_{i2}(1-X) = B_1C_{j1}X + B_2C_{j2min}(1-X)$$

After the transformations we will get

$$X_{max} = \frac{1}{1+\dfrac{B_1(C_{i1min}-C_{j1})}{B_2(C_{j2min}-C_{i2})}};\ 0 < X < 1$$

or

$$X_{max} = \frac{1}{1+\dfrac{\left(B_1C_{i1min}/B_2C_{i2}\right)\left(1-C_{j1}/C_{i1min}\right)}{\left(C_{j2min}/C_{i2}-1\right)}} \quad (3)$$

The skor of limiting EAA protein mixture (calculated) depending on the proportion of the first component is described by the equation

$$C_{iS} = \frac{B_2C_{i2}\left(\dfrac{B_1C_{i1min}}{B_2C_{i2}}-1\right)X_{max}+1}{B_S} \quad (4)$$

or

$$X_{max} = \frac{1}{1+\dfrac{B_1(C_{i1min}-C_{j1})}{B_2(C_{j2min}-C_{i2})}};\ 0 < X < 1$$

Let's introduce additional variables and denote them

$$Z_i = \frac{B_1C_{i1min}}{B_2C_{i2}},\quad Z_j = \frac{B_1C_{j1}}{B_2C_{j2min}},\quad a = \frac{1-C_{j1}/C_{i1min}}{C_{j2min}/C_{i2}-1} > 0 \quad (5)$$

Substitute (3) in (4) and for the optimal ratio of the components the calculated content of the converted protein in the mixture $K_S = B_S C_{iS}$

or

$$K_S = B_2C_{i2}\left(\frac{Z_i-1}{1+aZ_i}+1\right) = B_2C_{j2min}\left(\frac{Z_j-1}{1+aZ_i}+1\right) \quad (6)$$

After transformations we have

$$K_S = B_2C_{i2}\frac{(1+a)Z_i}{1+aZ_i} = B_2C_{j2min}\frac{Z_j+aZ_i}{1+aZ_i} \quad (7)$$

Accordingly, the calculated excess protein

$$B_n = B_S - K_S = \frac{B_1-B_2}{1+aZ_i} + B_2 - B_2C_{i2}\frac{(1+a)Z_i}{1+aZ_i} \quad (8)$$

Will emphasize that we are talking about the calculated indicators. The cumulative effect of mixing can be obtained if the limiting EAA of the components do not coincide. Inequalities Zi < 1, Zj > 1 must be observed. In addition, we also note that in the process of the optimization considered, it is possible to change the limiting EAA, i.e. in the mixture, the limiting component is not the limiting EAA component, but a third one. Therefore, a verification (control) recalculation is necessary. And, if there is a specified situation, use the previous algorithm of direct calculation with variation X.

As an illustrative example, we demonstrate the results of the calculation of a mixture of Camelina seeds with collapsed lupine and linseed cake (Table. 4).

The proportion of the component and the fraction of the converted protein depend on the accuracy of protein content and its amino acid composition.

Table 4.

Indicators for the source component and mixtures

Indicator	**Camelina**	**Collapsed lupine**	**Linseed cake**	**Camelina + Collapsed lupine**	**Camelina + Linseed cake**	**Linseed cake + Collapsed lupine**
Share of the first component	100	100	100	36.0	71.7	55.4
Protein, % of total weight	27.0	40.3	30.9	35.5	34.3	36.1
Limiting amino acid	Isoleucine	Methionine+ Cystine	Lysine	* Lysine	Lysine Isoleucine	Lysine Methionine+ Cystine
Convertible protein, % of total weight	18.7	24.3	20.8	27.3	22.2	28.0
Excess protein in the mixture, % of total weight	8.3	17.0	10.1	8.2	6.0	8.1

*the change in the limiting amino acid

Data analysis (Table. 4) shows that the grain product, consisting of two components, has an increased content of convertible protein and a reduced content of excess protein compared to the original components. For example, the mixture "Camelina+lupine collapsed" contains in its composition of convertible protein – 27, 3 %, and "Camelina" and "lupine collapsed" - 18.7 % and 24.3 % accordingly.

4. Conclusion

There is presented an algorithm for calculating the proportion of convertible protein, and, consequently, excess protein, in the grain product. The natural experiment of forming effective mixtures in accordance with the considered approach to their formation in the considered variants (samples) leads to more or less success. According to the results of the calculation, despite the decrease in the total protein of the mixture (relative to the component with the maximum protein content), the proportion of converted protein increases and, accordingly, the proportion of excess is reduced, compared with similar indicators of the component. In this case, the mixture may be cheaper than the most expensive component. Similarly, it is possible to consider mixtures of other oilseeds and legumes.

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