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Nutrition and metabolism of proteins and amino acids

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Abstract
Protein is the most abundant nitrogen-containing compound in the diet and the body. Proteins are formed when L-α-amino acids polymerize via peptide bond formation. Amino acids have similar central structures with different side-chains determining the multiple metabolic and physiological roles of free amino acids. Indispensable (essential) amino acids cannot be synthesized by humans from materials ordinarily available to cells at a speed commensurate with the demands of human growth and maintenance. The requirements for indispensable amino acids can be defined as "the lowest level of intake that achieves nitrogen balance or that balances the irreversible oxidative loss of the amino acid, without requiring major changes in normal protein turnover and where there is energy balance with a modest level of physical activity." For infants, children, and pregnant and lactating women, requirements would include protein deposited and secretion of milk proteins.

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1. Introduction
Protein is the most abundant nitrogen-containing compound in the diet and in the body. It is one of the five classes of complex biomolecules present in cells and tissues, the others being DNA, RNA, polysaccharides, and lipids. The polymerization of L-α-amino acids through synthesis of peptide bonds contributes to the formation and structural framework of proteins. These may contain two or more polypeptide chains forming multimeric proteins, with the individual chains being termed subunits. Proteins are the workhorses in cells and organs and their building blocks are the amino acids, which are joined together according to a sequence directed by the base sequence of the DNA (the genome), and so they serve as the currency of protein nutrition and metabolism. The Human Genome Project completed in 2000 revealed that the human genome consists of only 30 000 genes, whereas there may be hundreds of thousands of proteins that are responsible for giving a human its particular characteristics and uniqueness. A new field of nutrition research has now opened up and is referred to as "nutrigenomics," which is the study of how nutrition and genomics interact to influence health. Proteins and amino acids fulfill numerous functions

Fig 1

1.1 Classification
Proteins can be classified as

a) Simple proteins. On hydrolysis they yield only the amino acids and occasional small carbohydrate compounds. Examples are: albumins, globulins, glutelins, albuminoids, histones and protamines.
b) Conjugated proteins. These are simple proteins combined with some non-protein material in the body. Examples are: nucleoproteins, glycoproteins, phosphoproteins, haemoglobins and lecithoproteins.
c) Derived proteins. These are proteins derived from simple or conjugated proteins by physical or chemical means. Examples are: denatured proteins and peptides.

1.2 Factors other than diet affecting protein and amino acid requirements

Not every one of the same age, body build, and gender has the same nutrient requirements. These differences may be due, in part, to variations in genetic back- physiological requirements for nutrients among individuals For example, as already discussed, the growing infant or child requires higher nutrient intakes per unit of body weight than does the adult. Besides energy, for which the daily requirement declines with age because of reduced physical activity, it appears that the nutrient needs of healthy aged subjects do not differ significantly from those of young adults. Nevertheless, a characteristic of aging is an increased incidence of disease and morbidity, which is likely to be far more important than age per se in determining practical differences between the nutrient requirements of younger adults and elderly people. Ground. Various environmental, physiological, psychological, and pathological influences affect the variability in, Agent, host, and environment factors that affect protein and amino acid requirements and the nutritional status of the individual.

1.3 Protein Digestion and Metabolism

Ingested proteins are first split into smaller fragments by pepsin in the stomach or by trypsin or chymotrypsin from the pancreas. These peptides are then further reduced by the action of carboxypeptidase which hydrolyzes off one amino acid at a time beginning at the free carboxyl end of the molecule or by aminopeptidase which splits off one amino acid at a time beginning at the free amino end of the polypeptide chain. The free amino acids released into the digestive system are then absorbed through the walls of the gastro intestinal tract into the blood stream where they are then resynthesized into new tissue proteins or are catabolyzed for energy or for fragments for further tissue metabolism

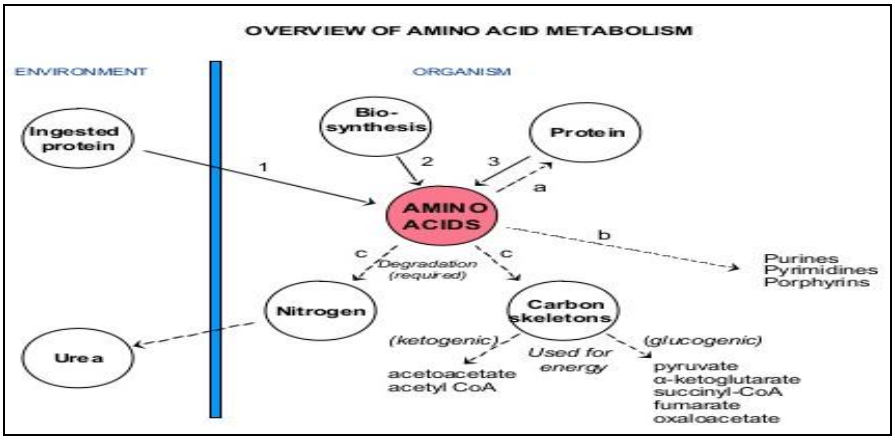

Fig 2

1.4 Essential and Non-essential Amino Acids

Salmon, trout and channel catfish fed diets devoid of arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan or valine failed to grow. These same fish fed diets devoid of other L-amino acids grew as well as fish receiving all 18 amino acids tested. The nitrogen component in the test diets was made up of 18 L-amino acids in the pattern found in whole egg protein. All fish on test recovered rapidly when the missing amino acid was replaced in the diet. The slope of the growth curve of the recovery group was identical with that of fish receiving the complete amino acid test diet.

Dispensable amino acids tested were alanine, aspartic acid, cystine, glutamic acid, glycine, proline, serine, and tyrosine. These amino acids were found to be not essential for the growth of salmon, trout and channel catfish.

Quantitative studies on the requirements of the 10 indispensable amino acids used a casein-gelatin mixture supplemented with crystalline L-amino acids. The test diet had an amino acid pattern of 40 percent whole egg protein for the nitrogen component. Experiments conducted with carp and eel showed a similar lack of growth when an indispensable amino acid was absent from the diet.

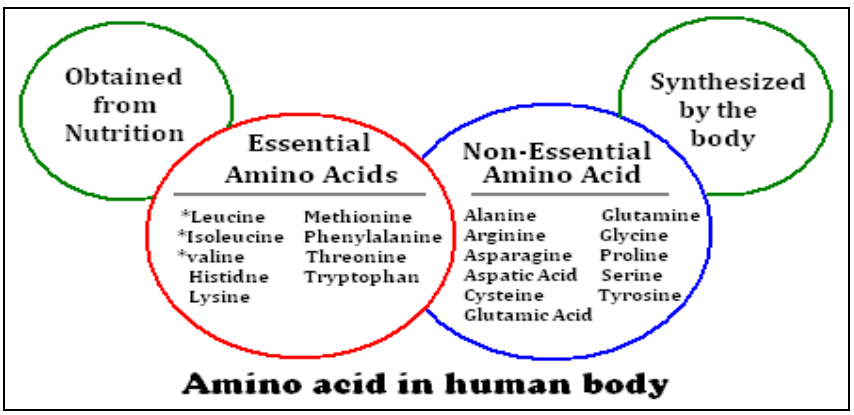

Fig 2

1.5 Essential Amino Acids and Protein Quality

If the essential amino acid requirements of fish are known, it should be possible to meet these needs in culture systems in a number of ways from different food proteins or combinations of food proteins.

Phenylalanine is spared by tyrosine. It is not known to be chemically modified nor rendered unavailable by the harsh conditions to which feedstuff proteins are normally subjected during processing. Measurement of phenylalanine in proteins is uncomplicated so that the provision and evaluation of phenylalanine in proteins in practical diets presents little difficulty.

Lysine is a basic amino acid. In addition to the amino acid group normally bound in peptide linkage, it also contains a second, amino group. This amino group must be free and reactive, otherwise the lysine, although chemically measurable, will not be biologically available. During the processing of feedstuff proteins the amino group of lysine may react with non-protein molecules present in the feedstuff to form additional compounds that render the lysine biologically unavailable.

Methionine is spared by cystine. However, measurement of the methionine content of feed proteins is not easy as the amino acid is subject to oxidation during processing. After processing, methionine may be present as such or as the sulphoxide or as the sulphone. The sulphoxide may be formed from methionine during acid hydrolysis of the feed protein prior to measurement of its any-no acid composition. Acid hydrolysis of proteins before analysis disturbs the original equilibrium between the two compounds so that the composition of the hydrolysate no longer reflects that of the protein. In determining the methionine content of pure proteins, oxidation of the amino acid to methionine sulphone is normally quantitative. In the case of feed proteins, however, this will not reveal how much methionine or methionine sulphoxide was present in the protein prior to performate oxidation and hydrolysis.

Methionine sulphoxide may have some biological value for fish which may have some capability of reconverting it to methionine and thus partially make up for some of the methionine oxidized during processing.

Methods have recently been reported for measurement of methionine in proteins using an iodoplatinate reagent before and after reduction with titanium trichloride, to give values for both methionine and the sulphoxide in the original protein. A method for measuring methionine specifically by cyanogen bromide cleavage has also been described. Both methods remain to be independently assessed. Microbiological assay of methionine in feed proteins is a valuable tool although there is the danger that oxides of methionine may differ in their activity for micro-organisms and misrepresent values.

Fig 3

1.6 Supplementing Diets with Amino Acids

One solution to the use of proteins that are relatively deficient in one or more amino acids is to supplement the protein with appropriate amounts of the amino acid needed in practical diets. Fish appear to utilize free amino acids at various degrees of efficiency.

Young carp, Cyprinus carpio, were shown to be unable to grow on diets in which the protein component (casein, gelatin) was replaced by a mixture of amino acids similar in overall composition. A trypsin hydrolyzate of casein was equally ineffective. However, if a diet containing free amino acids as the protein component is carefully neutralized with NaOH to pH 6.5-6.7 then some growth of young carp does occur. This growth was markedly inferior to that occurring on a comparable casein diet under the same conditions.

Channel catfish are also unable to utilize free amino acids given as supplements to deficient proteins. When soybean meal was substituted isonitrogenously for menhaden meal, growth and feed efficiency of channel catfish were substantially reduced. Addition of free methionine, cystine or lysine, the most limiting amino acids, to these soy-substituted diets did not enhance weight gain.

Raising the arginine level of catfish diets from 11 to 17 g/kg by isonitrogenous substitution of gelatin for casein enhanced weight gain significantly but the addition of free arginine, cystine, tryptophan or methionine to casein had little effect on growth or food conversion.

Salmonids are able to utilize free amino acids for growth. A zein-gelatin diet supplemented with lysine and trytophan was shown to be markedly superior to an unsupplemented zein-gelatin diet for rainbow trout when weight gain and protein utilization were used as criteria.

Several investigators have demonstrated the potential of supplementing amino acid deficient proteins with limiting amino acids in diets for salmonids. Casein supplemented with six amino acids produced feed conversion ratios with Atlantic salmon similar to those obtained when an isolated fish protein was used as the dietary protein source. Soybean meal

supplemented with five or more amino acids (including methionine and lysine) was a superior protein source to soybean meal alone for rainbow trout. Single additions of methionine and lysine did not, however, improve the value of soybean meal. These results suggest that the amino acid spectrum of the isolated fish protein they used may possibly approximate the amino acid requirement of rainbow trout. The nutritional value of a soy protein isolate could be enhanced by supplementing it with the first limiting amino acid; i.e., methionine.

Diets containing, as protein component, fishmeal, meat and bone meal, and yeast and soybean meal could be improved by supplementing with cystine (10 g/kg) and tryptophan (5 g/kg) together. Fishmeal can be entirely replaced without a reduction in food conversion rate in diets for rainbow trout by a mixture of poultry by-product meal and feather meal together with 17 g lysine HCL/kg, 4.8 g DL-methionine/kg, and 1.44 g DL-tryptophan/kg.

2. Conclusion

The purpose of this chapter was to provide a general overview of human protein and amino acid metabolism and a basis for an improved appreciation of the metabolic determinants of the requirements for protein (nitrogen) and for specific amino acids. With the recent beginning of the postgenome era, functional genomics, proteomics, and metabolomics will take on an increasingly important basic and applied research focus in biology. Thus, it will be even more critical for students to understand the physiology of human protein metabolism at its various levels of biological complexity (cell, organ, and whole body) and its nutritional corollaries.

There are certain areas of research in protein nutrition where more knowledge will equip nutritionists to make the best use of available food supplies. An example is the influence of the ratio of total essential or indispensable amino acids to total nitrogen and amino acid requirements for different physiological states. Another is the need for a functional definition of protein requirements (e.g., indices) for maximum resistance to disease and enhanced physical performance. These are some of the challenges facing nutritionists in the future. It is hoped that this chapter will serve as an appropriate catalyst for further learning in this area of human nutrition.

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