Criteria and Significance of Dietary Protein Sources in Humans

Summary of the Workshop with Recommendations

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The production of a sufficient supply of food protein sources, of adequate quality, to meet the requirements for nitrogen and amino acids for humans will be a major challenge for the future, as population growth continues throughout the world. There remains a need for clear answers to the conceptual questions of nitrogen and amino acid requirements and amino acid bioavailability and to practical questions regarding the routine and accurate evaluation of the ability of given protein sources to satisfy human nitrogen and amino acid requirements.

As discussed by Reeds (2000) and Young (2000), the nutritional requirement for dietary protein consists of three components: 1) amino acids that are nutritionally indispensable under all conditions (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine); 2) amino acids that can become conditionally indispensable under specific physiological or pathological conditions (e.g., cystine, tyrosine, taurine, glycine, arginine, glutamine and proline); and 3) nonspecific nitrogen for the synthesis of the nutritionally dispensable (nonessential) amino acids (aspartic acid, asparagine, glutamic acid, alanine and serine) and other physiologically important nitrogenous compounds.

It is usually accepted that the nutritive value of food protein sources is primarily dependent on the level and bioavailability of the first component of the protein requirement, i.e., the biologically available content of the nutritionally indispensable amino acids. Therefore, it follows that the nutritional quality of a protein can be determined from the efficiency with which a given dietary source supports the requirement for indispensable amino acids.

The physiological picture, however, is complex, and the work discussed by Reeds (2000) suggests that differences in dietary protein utilization may also occur with protein sources that also differ in their dispensable amino acid profile. Moreover, as discussed by Tomé (2000), the efficiency of dietary nitrogen and amino acid utilization is closely dependent on the level of protein intake. Nevertheless, as presented by Young (2000), a major emphasis to date in protein quality evaluation has been given to the definition of reference indispensable amino acid requirement profiles. Clearly, then, there are a number of critical issues to be resolved, and these include i) choice of the reference indispensable amino acid pattern, ii) measurement of protein (amino acid) digestibility and iii) the expression of the scoring index that predicts the ability of a protein source to satisfy the dietary requirement, when consumed either alone as the sole protein intake or as part of a mixed source of dietary proteins.

These various issues were the focus of the presentations made during the workshop, with questions of the metabolic basis for the requirements for, and nutritional significance of, the amino acids being considered by Reeds (2000) and the quantitative estimates of the requirements for nitrogen and indispensable amino acids being discussed by Young (2000). These metabolic and nutritional aspects are relevant to an evaluation of the reference amino acid requirement patterns proposed by FAO/WHO/UNU (1985) and then used by the 1991 FAO/WHO Expert Consultation. The latter consultation proposed, as an interim recommendation, use of the amino acid requirement pattern for preschool-age children for the evaluation of dietary protein quality for all individuals >1 y old. This was recommended because the 1985 FAO/WHO/UNU adult amino acid requirement pattern was no longer thought to be valid. As reviewed by Young, investigations carried out during the past two decades with tracer techniques, as well as other lines of evidence, strongly support this general position taken by the 1991 FAO/WHO Expert Consultation.

The procedure of amino acid scoring and, specifically, the protein digestibility–corrected amino acid score (PDCAAS) method, as proposed by the 1991 FAO/WHO Expert Consultation, takes into account the concentration...
of the limiting amino acid in the food protein, and it is expressed as the percentage of the same limiting amino acid in a reference amino acid pattern. This pattern is calculated in reference to the ability of a protein source to supply individual indispensable amino acids when consumed at a relatively low or safe protein intake level of 0.7 g/kg/d. At this protein intake level, adequate diets may have to contain a significant percentage of high quality protein sources or complementary mixture of plant protein sources. As discussed by Tomé (2000), the organism readily adapts to the level of protein ingestion so amino acid balance can be achieved over a large range of intakes. In addition, in the PDCAAS approach, a digestibility factor is included to take into account differences in the digestibility of the different protein sources. As discussed by Darragh and Hodgkinson (2000) and by Metges (2000), protein and amino acid digestibility is a complex concept; recent findings on this aspect of protein nutrition clearly demonstrate significant differences in the effect of the protein ingested, and of the diet as a whole, on endogenous nitrogen secretion in the gut, the relationships between fecal and ileal nitrogen digestibility and the relationships between total nitrogen and individual amino acid digestibility. In addition, the availability of nitrogen and amino acids varies with protein source and is affected by the presence of antinutritional factors, processing treatments and interaction among other components of the diet. All of these should be taken into account in a comprehensive evaluation and accurate prediction of dietary protein quality.

Enhanced knowledge about the physiology and regulation of amino acid metabolism in vivo leads to the suggestion that it is not necessary to consume complementary proteins at the same time and that separation of such proteins among meals during the day still permits food protein complementation to be effective. This may be of particular importance in considerations of the overall utilization of lysine in a diet based largely on cereal grains; the free lysine pool in tissues, particularly in the skeletal muscles, could serve to buffer the consequences of a low lysine content of a meal, such as one based on wheat or maize. Subsequent ingestion of a protein source rich in high lysine (e.g., meat or milk protein) during a following meal could then replenish the depleted lysine pool. A protein with a higher lysine content might be beneficial for this metabolic purpose and possibly needed in smaller amounts than another complementary protein with a somewhat lower lysine content. This may be because not all of the excess lysine intake will be used to replenish the lysine pool due to ongoing amino acid catabolism, demanding, therefore, a richer, follow-on supply of dietary lysine.

Furthermore, there is a diurnal cycle of nitrogen retention and loss that is affected by the frequency of ingestion and composition of protein-containing meals. Differences in the metabolic fate and retention of dietary nitrogen can be measured acutely during the repletion phase of the prandial and postprandial states in humans after the ingestion of different dietary proteins. This paradigm might represent an approach for the further validation of the PDCAAS scoring method. For instance, comparison of the nontruncated PDCAAS values of the food protein sources are in the following order: milk > soy > pea > wheat, with values of 120 (sulfur amino acids), 99 (sulfur amino acids), 73 (sulfur amino acids) and 36 (lysine), respectively. For comparison, measurements of the efficiency of postprandial nitrogen retention, as described by Tomé, are in this exact order. These observations indicate that postprandial nitrogen retention might offer a sensitive method to discriminate between different protein sources of differing quality.

Therefore, from the foregoing, the evaluation of the quality of protein supply should, as Schaafsma (2000) points out, ideally take into consideration i) the ability of the protein to satisfy nitrogen and amino acid requirement when used as the sole or principal protein source and ii) the capacity of the protein source to complement another protein source deficient in one or more individual amino acids (e.g., the capacity of animal protein to complement plant protein deficiencies in either lysine or the sulfur-containing amino acids). These two different aspects of protein quality should preferably be taken into account in an amino acid scoring procedure. Milk or meat proteins, e.g., can fully satisfy all indispensable amino acid requirements when ingested as the sole protein source at a level of 0.7 g/kg/d. Here, the protein quality or amino acid score would be 100.3.

In addition, milk protein (or other animal proteins) serves as a rich source of lysine, threonine and the sulfur-containing amino acids, and so they would be complementary for lysine-, sulfur-containing amino acid- or threonine-deficient protein food sources. It may be appropriate, e.g., to identify the score for milk protein as 128, 123 or 120 for lysine, threonine and the sulfur-containing amino acids, respectively.

Emerging from these various observations, a series of recommendations appear to be appropriate:

1) The Amino Acid Scoring Pattern for the adult proposed in 1981 by the Joint FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements (1985 report) significantly underestimates the indispensable amino acid requirements. This was the conclusion of the 1989 FAO/WHO Consultation on Protein Quality Evaluation (FAO 1991) that proposed, as an interim procedure, use of the 1985 FAO/WHO/UNU amino acid requirement pattern for preschool-age children to score dietary protein quality for all age groups except infants. Research conducted since 1989 has continued to support the general validity of this proposition. Hence, it is now recommended that a new United Nations consultation be convened to review and establish an updated international amino acid scoring pattern for protein quality evaluation. A similar conclusion was made at the Third International Food Data Conference held at FAO in Rome in July 1999.

2) The principle of the PDCAAS procedure appears to be generally accepted as a routine procedure for protein quality evaluation. However, it is time to revisit and evaluate this method in greater detail. Major aspects that deserve attention are the measurements of the digestibility of the protein sources, whether truncation of the score of high quality proteins downward (from >100 to 100) is appropriate and the inclusion in a scoring index of a value that indicates the capacity of individual protein sources to complement protein sources that are deficient in specific indispensable amino acids. It is also timely to further evaluate the use of ileal rather than of fecal digestibility for inclusion in the scoring procedure and to determine whether total dietary nitrogen digestibility represents a valid indicator of the bioavailability of the limiting individual amino acid or acids. The importance and role in host amino acid metabolism of the metabolic activity of the intestinal microflora also must be far better understood and quantified if necessary.
Finally, the PDCAAS approach should be further validated and tested as a routine procedure through a comparison with other approaches, including in vivo studies of dietary protein utilization in humans. The deposition of nitrogen during the prandial phase appears to be a critical factor in determining food protein quality, and this might be used to help discriminate nutritionally significant differences among dietary protein sources.

These various propositions should now be discussed, among others, under the auspices of a United Nations–convened, international expert consultation at an early opportunity.

**LITERATURE CITED**


