It is convenient to consider factors which can influence the utilization of dietary protein under three separate headings.

1. Those which result from the interaction between the chemical composition of the diet, and the metabolic processes of the consumer, and which include:

   1.1 Amino acid composition of the protein.
   1.2 The ratio of protein to total energy-yielding sources in the diet
   1.3 The level of vitamins and minerals.

2. Physiological and pathological factors.

3. Finally, one factor which because of its importance merits separate consideration, namely the degree to which the energy needs of the consumer are met. In many practical situations, protein anabolism is limited by the level of caloric intake, and this in turn may depend simply upon the amount of food available, or indirectly to the effect upon appetite of a deficiency or surplus of some nutrient, or to the existence of an infection or infestation.

1.1 Amino Acid composition

After more than 20 years, the quantitative relationship between amino acid composition and the nutritive value of proteins suggested by Block and Mitchell, still seems the most reasonable and practically useful description that has so far been devised. A review of reference patterns and methods of calculation of protein scores will be found under item 13.

Block and Mitchell's approach requires qualification only in as far as we now have a much more detailed understanding of the factors other than amino acid composition which affect nutritive value, and which therefore modify the relationship between chemical score and the effective protein values of diets and foods consumed under the varied conditions encountered in practice.

1.2 The level of protein in the diet

When a large meal of protein is absorbed, the concentrations of free amino acids in the plasma rise to values greatly in excess of the fasting levels, particularly in the portal blood. Under these circumstances, the pattern of amino acids available at the site of protein synthesis is probably dominated by the proportions obtaining in the food, although the liver may possibly exert some modifying effect upon the relative proportions through rapid enzyme adaptations (Elwyn1). As the amount of protein absorbed with each meal is reduced, the proportion of exogenous amino acids...
relative to those originating from the turnover of tissue proteins will fall, and the mixture available for anabolism will reflect the proportions in the food protein to a smaller and smaller extent as protein intake is progressively reduced.

It is thus unlikely that any measure of protein quality will be found to bear a consistent and constant relationship to amino acid composition, irrespective of the level of intake.

In fact Rafalski\(^2\) has shown that for a number of proteins, values of Net Protein Utilization measured at very low intake levels (~1% of the diet) are typically about 20 and are not correlated with the nutritive values measured at higher levels of intake. As the level in the diet is increased, however, NPU rapidly rises towards maximum values which occur in each case at around the level of protein which is sufficient for maintenance. These conditions have been described by Miller and Payne\(^3\) as appropriate for the measurement of NPU standardised. Such values probably best reflect differences in quality due to variations in essential amino acid content, and could therefore be expected to correlate best with protein scores.

At protein levels in the diet higher than those needed for maintenance, NPU\(^s\) decline with increasing concentration; although still reflecting differences in amino acid composition. Under these conditions NPU values have been termed operative by Platt an Miller\(^4\). The dependence of NPU operative upon protein concentration has been described by many authors, working with a number of species (for list of 10 references see working paper on Interrelationships between Protein and Calorie Requirements by Waterlow and Payne under item no. 15). This effect should not be regarded simply as a wastage of amino acids surplus to requirements, since the decline begins immediately the level rises above maintenance. It is in fact a reflection of the adaptation of the animal to changes in dietary composition. Hegsted and his associates\(^5,6\), have denied the existence of this effect, on the grounds that the relation between retained N and intake N in test animals fed a series of diets with increasing levels of protein, approximate to a straight line, and that thus NPU can be regarded as a constant. However, the magnitude of the change in efficiency with protein level observed by other workers, is such that only a negligible departure from linearity is to be expected under these experimental conditions. In fact the NPU values of the individual diets when calculated from the data published by Hegsted et al., always show a decline in efficiency with increasing level. Although it may seem convenient for a protein assay procedure to exhibit a linear dose response relationship, the slopes of these lines can only be regarded as measures of the average nutritive value of a series of diets of varying composition, and these may depart considerably from the actual value of the conversion efficiency of any one diet in the series. This probably accounts for the fact that Hegsted and Chang’s estimates of the nutritive value of low quality proteins such as soy and wheat gluten, are much lower than those reported by any other workers.

In order to assess the protein value of diets and foods in relation to the needs of infants and young children, we need to know the value of NPU operative. This may be measured directly, as suggested by Platt and Miller\(^4\), or calculated by means of prediction equations which take account of both the chemical score (or NPU standardised) and of the effect of protein concentration. A number of authors\(^3, 7, 8\) have proposed equations of varying degrees of complexity, although over the range of concentrations encountered in the human diets the simple linear form\(^1\) is sufficiently accurate.
1.3. Effects of a vitamin or mineral deficiency

Clearly any dietary deficiency which either immediately, or after a period of time, leads to a depression of growth, will inevitably interfere with protein utilization. This can arise either because of a direct effect of the deficiency upon N metabolism, as for example lack of B12 or essential fatty acids or a deficiency of sodium. Or alternatively the deficiency may act through a depression of appetite to the point where energy intake becomes the factor limiting N retention as happens for example with diets low in potassium. In practical situations, multiple deficiencies probably give rise to combined effects, which are further complicated by time factors.

II. Physiological factors and Pathological Conditions

2.1 The effects of age

Studies of N utilization and of protein quality have been most frequently carried out using young animals capable of fast growth, and the efficiency of protein utilization is probably maximal under these conditions. Evidently with older animals there will be a reduction of the level of dietary protein which is adequate to meet growth requirements. Efficiency of protein utilization up to this level is probably little affected by age, but diets containing protein surplus to requirements will be inefficiently utilized. Rakowska et al.

2.2 Pregnancy and Lactation

Naismith has given evidence to show that during the early part of pregnancy in the rat, N is retained more efficiently from high protein diets than it is by non pregnant animals of the same age, so that during this anabolic phase, efficiency of utilization probably rises to values normally found in younger animals. Blaxter has reviewed the evidence pertaining to the biological values of proteins for lactation, and concludes that these probably differ little from those for growth.

2.3 Pathological Conditions

Infections and infestations are most likely to lead to reduced efficiency of N utilization, either directly, because of impaired absorption, to metabolic disturbances, or to competition for N between a parasite and its host. Or indirectly because of reduced food intake sometimes coupled with an increased energy expenditure in febrile conditions.

III. Caloric Insufficiency

The effect of reduced energy intakes upon N balance is reviewed in detail in the paper on Interrelationships between protein and energy requirements (Agenda, item no. 15). It is sufficient to say that in terms of efficiency of protein utilization, values are reduced when the caloric intake falls below a certain critical level, declining towards zero at an intake equivalent to the basal energy expenditure. At levels of intake above the critical point however efficiency is a constant for a given protein: calorie ratio in the diet. Miller and Payne, Narayana Rao and Morrison.
IV. General conclusions

In attempting to assess the diet of an individual, all of the factors discussed above should ideally be taken into account, and of these, probably that of caloric insufficiency is the most important both in terms of the magnitude of its effect upon protein utilization, and of its widespread incidence. However, the information necessary to make such an individual assessment is rarely available, and it is often only possible to regard the results of surveys as an indication of the general pattern of diets and of the types of foods consumed. In these circumstances, the most appropriate index of protein utilization is the NPU operative of the diets and foods measured with young animals. These give an indication of the net effective amount of protein available from the diets under the best practical conditions (assuming a sufficient quantity is available to meet calorie needs), and makes it possible to assess their potential adequacy in relation to the needs of the most vulnerable groups in the community.

REFERENCES

1. Elwyn, D. In Mammalian Protein Metabolism. 4: Ch. 37. (Editors H. N. Munro) Academic press, New York


