PLANT BASED SOURCES OF PROTEINS AND AMINO ACIDS IN RELATION TO HUMAN HEALTH

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Summary

Plant proteins in the human diet include a diverse range, which vary in terms of amino acid composition and digestibility. They are perfectly capable of satisfying human needs for all ages when consumed in appropriate mixtures. However, monotonous diets based on unsupplemented cereals, and especially some root crops, may be inadequate sources of indispensable amino acids, especially for children. While protein quantity is not an issue, digestibility is a problem for some cereals and is generally poorly understood. The adequacy of most common plant protein sources for children is discussed. Calculation of an amino acid score is problematic because of the lack of agreement on reference amino acid requirement patterns. New maintenance and age-related amino acid requirements pattern have been suggested which appear valid when used to score plant proteins, indicating values similar to, or less than, the biological value measured directly in young children. When used to score plant-based diets in India, no marked deficiencies are identified for adults, whilst for children deficiencies are only

identifiable in very young children and these are relatively minor. Thus inadequate amino acid supply is unlikely to be an issue with most cereal-based diets.

The health implications of plant protein diets is difficult to assess in relation to the proteins *per se* because of the general benefit of diets rich in cereals fruit and vegetables, but several potential factors have been proposed These include metabolic responses to a lower essential amino acid and lower overall protein intake, but newly emerging epidemiological data is challenging the view that low protein plant based diets are beneficial, with data that high protein intakes reduce risk of cardiovascular disease, hypertension and osteoporosis.

However, with increased plasma IGF-1 bioactivity, a major risk factor for hormone sensitive cancers, and with dietary protein intake a determinant of plasma IGF-1 levels, the health implication of the level of dietary protein is difficult to resolve. It is most likely that phytoprotectant factors associated with plant protein sources, especially the isoflavones in soya, can reduce the risk of chronic disease, although little is known about the detailed mechanisms.

1. Introduction

Of the several thousand plant species that are assumed to have contributed to the human diet in the past, and the 150 species that have been cultivated for commercial purposes, most of the worlds population depends on only about 20 different plant crops. These plant protein sources provide 65% of the world supply of edible protein and are generally divided into cereals, legumes and other vegetables, fruits and nuts, with cereal grains providing almost half (47%) of world protein supplies. Plant protein sources in the developed countries constitute only about a third of intake: i.e., 31% of protein intake in the US diet and 36% in the UK, but are the major source (about 80%) in the developing countries, of which cereals predominate (see Table 1). Of these wheat, (43%), rice, (39%) and maize, (12%) account for the main part. Plant protein sources can differ from animal sources in terms of digestibility, amino acid composition, the presence of anti-nutritional factors which adversely influence digestibility and safety and of phytoprotectant factors (such as antioxidants, phytoestrogens, etc.), which may be advantageous by mediating disease protection. Due to this latter factor, together with the current guidelines to reduce animal fat and limit meat intakes, an increased consumption of plant food sources (fruit and vegetables, bread, cereals and potatoes) has been universally proposed as part of the Healthy Diet.

Although it is frequently pointed out that plants can provide all of human protein needs, it is nevertheless the case that the misconception persists that they are nutritionally inferior to animal proteins. This is because of both complex social and cultural attitudes towards meat and because of the scientific tradition of protein quality evaluation in animals. In fact, the important nutritional question is not whether plant proteins can completely provide for human amino acid needs, since this has been established for all ages. Rather, the question is whether this is an easy task in practice, i.e., achievable with relatively unsupplemented, low-cost cereal or other staple diets available to poor developing communities or only possible with the much higher cost, carefully selected mixed diets consumed by affluent vegetarians.

Country	Protein	P:E ratio	Protein sources: animal		Protein sources: cereal		Pulse/ soya	rest	lysine
	g d-1	% energy	g d-1	%	g d-1	%	g d-1	g d-1	mg d-1
Food balance sheets									
US	113	12.1	73.5	65.0	24.6	21.8	2.0	12.9	7598
UK	91	11.0	52.3	57.5	22.9	25.2	2.3	13.5	5815
Tunisia	91	10.9	19.0	20.9	55.6	61.2	6.0	10.3	3911
Egypt	87	9.4	12.9	14.8	59.6	68.3	5.8	9.0	3502
Brazil	66	9.3	27.1	41.1	22.6	34.3	10.4	5.8	3918
Nepal	50	10.2	7.3	14.6	34.8	69.5	3.4	4.6	2132
Bangladesh	43	8.4	4.8	11.3	33.4	78.6	2.6	1.7	1883
Sierra Leone	34	8.0	6.9	20.3	17.0	50.0	4.6	5.5	1741
Food intake data									
UK omnivores	74	14.2	44.1	59.4	17.3	23.3	7.0	5.9	4824
UK vegetarians	54	12.7	18.1	33.6	18.7	34.8	9.4	7.6	2871
India (mean)	62	11.1	3.4	5.5	47.8	76.7	7.3	3.8	2413
Tamil Nadhu	46	9.7	2.4	5.3	29.0	63.6	6.6	7.6	2006
West Bengal	53	8.8	0.8	1.5	48.0	89.9	3.2	1.4	1869
Lysine requirements (at 65 kg body weight)									
FAO/WHO 1973									780
FAO/WHO 1991									3770
Toronto Breakpoint studies:			mean value						2795
			Safe allowance						4114
MIT scoring pattern									1950
Original N balance data recalculated									1209

Table 1. Protein and lysine content of diets in relation to estimates of the requirements.

2 Protein Quantity

Animal food sources are generally high protein, so that there is a clear relationship between protein intake and the proportion of animal foods, especially meat, in the diet. As shown in Table 1, the overall protein energy ratio of national food supply falls from 12.1% in the US to 8% in a Sub-Saharan African country, like Sierra Leone, as the animal protein intake falls from 74g d^{-1} to 6.9g d^{-1}. In the UK, the P:E ratio falls from 14.2% in omnivores to 12.7% in the small number of vegetarians, (non meat eaters) identified in the UK food intake survey. Thus, protein intakes of vegetarians are likely to be closer to the RNI, and some 20-30% of this, albeit small, sample were below it.

Whether this is a problem is to some extent debatable, but probably unlikely especially in developed countries given the overall lower morbidity and mortality of vegetarians compared with meat eaters. Firstly with the adult protein requirement equivalent to a P:E ratio of about 9% and 7% for the Reference Nutrient Intake (RNI) and Estimated Average Requirement EAR, i.e., 0.75g and 0.6g protein kg^{-1} in adults, (calculated assuming an energy requirement of 1.6* BMR), the lowest diets shown in Table 1 fall between the EAR and RNI for adults. Secondly, all of the values in Table 1, for protein as food supplies or intake, indicate P:E values higher than breast milk at 7%, since as shown in Table 2, only a few plant staples have a lower P:E ratio than this. Indeed. wheat and maize are "high protein foods" compared with breast milk if the energy density issue is ignored. Furthermore on the basis of a metabolic model for the protein requirement which includes a substantial adaptive component varying with intake (see below), there is by definition a correlation between intake and requirement, so that low intakes are unlikely to become associated with substantial prevalence rates of inadequacies until they fall close to the LRNI. Most importantly, at least as far as food supply data is concerned, wheat-based food supplies, such as Tunisia and Egypt with only 15-20% animal protein sources, clearly supply protein at levels close to that of predominantly animal based food supplies, as for the UK. This means that cereal based diets, especially those based on wheat, can supply protein at levels well above the human protein requirement. As for infants and children, the wide and successful use of soya based infant formula is proof that plant-based diets can be adequate for infants. On the other hand, the monotonous diets based on very low protein starchy root crops, such as cassava, may well supply inadequate protein intakes to ensure adequate height growth. In this context, it is interesting to note that in such cases, such as the stunted Bundi orphanage children described in the 1970s who were fed almost exclusively on the low protein starchy root Taro, stunting was the only observable symptom of any nutritional adequacy. They were otherwise healthy, without overt symptoms of Kwashiorkor, in support of the arguments that Kwashiorkor is not a protein-deficiency disease. The issue of whether stunting in children reflects inherent inadequacies of plant based diets as protein sources as opposed to other nutrient inadequacies is outside the scope of this paper, but as discussed below, it has been demonstrated that young children fed one of the hybrid varieties of maize (opaque-2(o_2), sugary-2(su_2) hybrid) (see *Molecular Genetic Improvement of Protein Quality in Maize*) as their sole protein and energy source (but with mineral and vitamin supplementation) grow in height and weight at rates similar to that achieved with casein. For these reasons, and with the nutritional adequacy question limited to the consideration of protein needs, then we can reasonably safely conclude that with the exception of some starchy roots, plant based diets available in most parts of the world are capable of providing adequate protein for all ages. Thus, protein quantity is unlikely to be an issue and the main question of their nutritional adequacy as protein sources is limited to their quality, i.e., digestibility and biological value.

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Biographical Sketch

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