SOYA PROTEIN—NUTRITION

World Need for Protein

N.S. SCRIMSHAW, Department of Nutrition and Food Science, Massachusetts Institute of Technology, Cambridge, MA 02139, and Senior Adviser, World Hunger Programme, United Nations University

ABSTRACT

On the basis of the 1973 FAO/WHO recommendations for average calorie requirements and safe protein allowances for healthy individuals, both calorie and protein intakes are generally deficient in the lower socioeconomic groups of developing countries, with calories apparently the more limiting in most cases. However, extensive data available since 1973 indicate that the 1973 protein allowances for healthy adults approximated the mean rather than the mean plus two standard deviations as intended. For those individuals in developing countries who are frequently unhealthy, requirements may be even higher. Children have considerably higher protein requirements for catch-up growth following episodes of acute infection; failure to obtain sufficient protein appears to be a major factor in the permanent stunting of such children. Requirements for dietary energy increase much less for catch-up growth than requirements for protein. Comparing calorie intakes with international estimates of requirements has limited validity because of the human capacity to adjust to a decreased dietary energy intake by reducing physical activity. No comparable adaptation is known for low dietary protein intakes; instead, under the conditions responsible for limited food availability, protein requirements are likely to increase because of acute and chronic infections. Although differences in protein quality can be demonstrated by experimental animal and human studies in which protein intake is grossly deficient, little difference is detectable in studies where protein intake is at requirement levels. Thus, soy and other legume and oilseed protein sources can replace animal protein to any degree in human diets.

INTRODUCTION

The life-sustaining importance of protein in human diets has at times been obscured by controversy over how much protein is required and whether protein or calories is the more limiting in diets of underprivileged populations. These issues are gradually being resolved by ongoing research and by better understanding of the factors involved. The result is a reaffirmation of the importance of efforts to meet the protein needs of vulnerable groups, with or without equal attention to energy needs and energy density of the diet, depending upon the group and the circumstances.

This paper presents evidence in support of the growing consensus that the current international "safe protein allowance" for adults is appropriate only as an approximation of the mean requirement whose coefficient of variation, based on one standard deviation, is in the range of 15-20%. Moreover, for both children and adults, appropriate allowances must be made for catch-up periods after times of infection or other stress.

Energy requirements cannot be assumed from global estimates, but must be specified in terms of specific life-styles and environmental circumstances. One result of the current reappraisal is rejection of simplistic analyses of the relative significance of dietary protein and dietary energy, based on comparison of the 1973 FAO/WHO allowances (1) with food availability or the results of food consumption surveys. Another result is recognition that agricultural and economic planning that does not include concern for protein as well as energy needs can have harmful consequences for human health and welfare.

Whereas most human populations may prefer liberal amounts of animal protein in their diets, the relatively high cost and limited availability of animal proteins make it necessary for most nations of the developing world to supplement their largely cereal-based diets with legumes and oilseeds. Soy, which is traditional in Asian diets, has proved extraordinarily capable of providing an acceptable and relatively economical source of good-quality protein. It has also become an important source of protein in animal feeding.

Protein and Energy Requirements

The 1973 FAO/WHO report (1) gave 0.57 g of egg or milk protein per kg of body weight per day as the amount sufficient to meet the needs of nearly all of the adult populations of the world, when dietary energy needs are also met. When this amount was fed for 2-3 months in three successive studies (2-4) to healthy Massachusetts Institute of Technology (MIT) students, the changes in the first month of the studies were not significant. However, as the study continued, losses in lean body mass, altered liver transferase activity, and reduced serum protein and hemoglobin were observed, despite the provision of 10% extra calories in the initial studies. In other MIT studies in which meat, egg, milk or soy protein were given at several levels of intake below the requirement level, the mean zero balance intercept was close to the 0.57 g per kg value. Similar results have been obtained by Calloway et al. in Berkeley (5,6).

If the 1973 allowance was not sufficient for normal healthy U.S. students receiving this amount of egg or other high-quality protein along with abundant calories, how appropriate could it be for the populations of developing countries, whose diets are of poorer quality and where environmental circumstances might place added stress on protein needs? To gather data on this point, the United Nations University has sponsored, in a number of countries, nitrogen balance studies at multiple levels of intake of protein either from egg or from the usual diets, using a standard protocol (7). Some groups of subjects were university students, but groups of individuals were also selected who were exposed to the frequent diarrheal disease and enteric parasitism so common in developing countries. Studies are being carried out in Korea, Thailand, the Phillippines, Mexico, Guatemala, Colombia, Chile, Brazil, Nigeria, Egypt, Turkey and India, with relevant data also being provided by groups in Berkeley, Taipei, Cambridge, Massachusetts, Cambridge, U.K. and Moscow.

The studies are in various stages of completion, but a workshop held in May, the results of which are soon to be published by the United Nations University (8), provides evidence consistent with the conclusions of the MIT and Berkeley research. Table I, taken from that publication, shows mean intercepts for nitrogen balance for single protein sources that range from .52-.70 g per kg for animal protein, and .71-.91 for soy protein isolate. A 5 mg per kg integumental loss is assumed. The pooled standard deviation of these studies gives a coefficient of variation of 18%. Therefore, the mean plus two standard deviations—the amount expected to be sufficient to cover the needs of 97.5% of the population—ranges from a low of .71 g/kg in one study with beef protein to a high of 1.25 g/kg for whole wheat protein. The "safe allowance" for mixed diets ranged from 1.03 in Mexico (corn and beans) to 1.18 in Colombia (beans and potatoes). These figures are at least one-third higher than would be estimated in the 1973 FAO/WHO report (1).

It is unlikely that changes of this magnitude from the 1973 recommendations will be required for children, the reason being that in attempting to ensure adequate protein for growth, including some catch-up, the allowances for children were based on age rather than on weight. Since most children in developing countries already weigh less for their age than the well-nourished children on whom the standards were based, this provides a margin of safety.

Whether the protein allowances are sufficient for normal variations in the growth of children who are within the upper ranges of weight for age of well-nourished children will require determination by the expert committee. The estimated allowances for normal growth are based on daily growth rates 1/365th of annual growth increments, despite the fact that actual growth patterns over short periods show great variability, and range from periods of zero growth to ones several times the daily average calculated on an annual basis. It is noteworthy that most children in groups considered well-nourished are already consuming considerably more protein than called for by the "safe allowance."

Children in developing countries, however, show even greater variation in daily growth rates, because during periods of catch-up from episodes of infection, daily growth rates even under village conditions may be up to nine times the daily average, if the diet is sufficient to permit it (7,9). Since protein requirements for growth after one year of age are about 12% of the total and increase during the pubertal growth spurt, such rates of catch-up growth would represent a significant increase in protein needs. Under these circumstances, there is increasing evidence that dietary protein rather than dietary energy is likely to be the factor that limits growth (7,10; Sheldon Margen, personal communication, 1980). The proportion of dietary energy used for growth, expressed as a percentage of the maintenance requirement, is only 3%, and expressed as a percentage of total energy requirements is only 2% (1). Thus, protein-energy ratios quite satisfactory for normal growth may become inadequate for catch-up growth; for example, a catch-up growth rate of six times the daily average would require approximately a 60% increase in total protein needs, and only a 10% increase in calorie needs.

Judging the relative significance of apparent protein and energy deficits in the diets of developing country populations is complicated by additional factors. The most important of these is that individuals cannot be in negative

TABLE I

Mean Requirement Based on Zero N Balance Intercepts and "Safe Allowances" for Various Protein Sources and Mixed Diets, Assuming an Integumental N Loss of 5 mg/kg and 18% Coefficient of Variation

Diet	No. of subjects	Country	Investigator	Mean requirement (g prot/kg)	"Safe allowance"[a] (g prot/kg)
Beef	7	U.S.[b]	Fajardo et al.	.52	.71
Milk	6	U.S.	Wayler et al.	.54	.73
Egg	8	U.S.	Puig et al.	.56	.76
Egg	7	Taiwan	Huang et al.	.59	.79
Beef/soy[c]	7	U.S.	Wayler et al.	.62	.84
Egg	8	Chile	Uauy et al.	.62	.84
Fish	8	Japan	Inoue et al.	.63	.86
Beef	6	U.S.	Puig et al.	.66	.91
Fish/soy[c]	8	Japan	Inoue et al.	.66	.91
Beef	6	U.S.	Wayler et al.	.69	.94
Milk	5	U.S.	Wayler et al.	.70	.95
Soy[c]	8	U.S.	Puig et al.	.71	.97
Mixed (corn-beans)	8	Mexico	Bourges et al.	.75	1.03
Mixed (rice, AP[d])	15	Taiwan	Huang et al.	.80	1.09
Soy[c]	5	Japan	Inoue et al.	.81	1.11
Mixed (cassava, AP, potato)	11	Colombia	Fajardo et al.	.82	1.12
Mixed (wheat, beans, milk)	7	Chile	Uauy et al.	.83	1.13
Wheat	6	U.S.	Uauy et al.	.84	1.15
Soy[c]	8	U.S.	Wayler et al.	.86	1.18
Mixed (beans, potatoes)	8	Colombia	Fajardo et al.	.87	1.18
Soy[c]	6	U.S.	Wayler et al.	.91	1.23
Wheat	7	U.S.	Fajardo et al.	.92	1.25

[a]Mean plus 36% (equivalent to two standard deviations calculated utilizing all data in this table).

[b]U.S. = work done at MIT.

[c]Soy protein isolate ("SUPRO").

[d]AP = animal protein.

energy balance indefinitely. When dietary energy is chronically low, survival requires adaptation to bring energy intake and expenditure into balance. This adaptation is, to a limited extent, metabolic, but mainly it is a decrease in physical activity. This has been demonstrated for children (11,12) as well as for adults.

Conversely, when individuals on restricted diets receive additional calories, activity may spontaneously increase (13). It now seems likely that the social patterns of some developing countries represent an adaptation to a chronic shortage of food. Certainly the caloric intakes suggested as average requirements in the 1973 FAO/WHO report would be excessive for activity patterns currently demanded of their populations. Similarly, many industrialized country populations have lower average energy requirements than given in the 1973 report, not out of adaptive necessity, but because of a lifestyle that calls for little physical exertion. The 1973 report did indicate that the average recommendations, based on a "moderately active population," might need to be adjusted for differing levels of activity of populations, but in practice this has rarely been done.

The above considerations lead to the conclusion that there can be no valid global estimates of calorie requirements, since these are determined by social and activity patterns of individuals and societies. For the developing world, the evaluation of diets limiting in both protein and energy is complicated by environmental and social conditions that tend to increase protein requirements (infectious disease, intestinal parasites, diets high in fiber, etc.). These conditions also increase energy requirements, but to a much lesser extent, and energy deficits are compensated for in most individuals by reduced physical activity, as discussed previously. Unfortunately, there is no known adaptation to protein deficiency except some increase in retention at deficient levels of intake. This mechanism does not operate, however, when protein intake meets requirements. Thus apparent deficits in dietary energy may have serious social consequences, even though they are not necessarily associated with physiological deficits. On the other hand, deficits in protein intake that are not apparent by current international standards, may have important effects on growth and development, resistance to infection and recovery from stress.

Protein Quality

Any consideration of world protein needs must consider protein quality as well as quantity. Traditional methods of evaluating protein quality in experimental animal and human subjects, however, measure utilization when the dietary intake is inadequate. It is necessary to distinguish clearly between these and the capacity of proteins to meet human requirements when they are fed at adequate levels. The former gives relative values among proteins and can best detect the damage to protein quality due to processing and other factors. Protein quality measurements based on deficient dietary intakes, however, overestimate the utilization of a protein when fed at levels adequate for maintenance and growth. These measurements also overestimate the significance of individual amino acid deficiencies. In the case of soy protein, methionine can readily be shown to be limiting retention at deficient levels of intake, but methionine addition in human subjects has no effect on retention of soy protein at requirement levels and above (14,15). For practical purposes, animal protein and good-quality soy protein are nutritionally interchangeable when consumed at or above requirement levels (16).

On the other hand, predictions as to the amount of any protein required for nitrogen balance based on N retention at deficiency levels will underestimate the amount required as determined when the zero balance intercept is calculated from multilevel studies (17). The amount underestimated is similar for soy protein that has not been damaged in processing and for protein of animal origin, but the discrepancy becomes progressively greater as dietary protein quality decreases. These issues are discussed in detail in a monograph developed by a committee of the International Union of Nutritional Sciences in collaboration with other groups scheduled for publication early in 1981 (18).

Future Protein Needs

Despite the misleading impression sometimes given by non-nutritionists, populations do not thrive on cereals alone, even when cereals provide a large percentage of the total energy and the majority of the protein in the diet. The cereal staple must be supplemented with small amounts of animal protein or with some other relatively more concentrated protein source, such as that from legumes and oilseeds. Overemphasis on cereal production alone has led directly or indirectly to a per capita decline in legume production and an increase in legume prices (19). In developing countries with cereal-based diets, the resulting decrease in availability and consumption of legumes has seriously affected poor populations and vulnerable groups such as preschool children and pregnant and nursing mothers.

Most populations supplement their cereal- or root- and tuber-based diets with fish, meat, eggs and other products of animal origin to the extent that they can afford to do so; as their economic status improves, their consumption of these foods increases. Since at best the efficiency of converting protein in feed ranges from about 26% for commercial egg production to approximately 4% for feed-lot beef, with milk, broilers and pork falling in between, affluent populations place far more demand on food supplies than poor populations do. This is illustrated by the fact that whereas for many developing countries a per capita intake of cereal of about 200 kg per person per year suffices to provide the bulk of the diet, in North America grain consumption is nearly 900 kg per person. However, only about 65 kg of the latter is consumed directly; the remainder is fed to animals and ultimately consumed in the form of meat, milk, eggs and other animal products.

The significance of this high demand in a world demanding more and more animal protein as a result of increasing population and affluence is not always appreciated. Moreover, both Japan and Western Europe depend heavily on U.S. soy meal exports to sustain their animal production. In both Eastern Europe and some developing countries, coarse grains and protein concentrates for animal feeding are simply not available in sufficient quantities to satisfy demand, and the resulting lack and high price of animal products threatens political stability. To the extent that foreign exchange is available, most of these countries import U.S. soy beans for animal feeding.

My purpose in repeating what is generally well known is to emphasize that rapid population growth is certain to continue for at least the next few decades, and this will increase the demand for protein disproportionate to the number of additional persons to be fed. Specifically, there will be an increase in demand for protein occasioned by the 2 billion people due to be added to the present world population of approximately 4 billion before the end of this century. There will be a large additional demand for protein, however, caused by rising affluence in a part of the world population. It is with this perspective that the future of soy protein in meeting world protein needs must be evaluated.

Soy will continue to be the basis for much of the animal production for more affluent populations. The increased demand already indicated for animal protein will put continuing pressure on soy production capabilities. However, there is every reason to believe that soy protein processed in forms that make it a functionally acceptable replacement or extender of animal products will play an increasing role in the diets of the more affluent, and will help to compensate to some degree for the high prices and limited supplies of products of animal origin.

In Asia, soy products eaten with rice have been a major factor in sustaining the population of this region that has nearly 60% of the world's population. Most of this soy has been consumed directly by humans, in contrast to its current use for feedings animals in much of the rest of the world. In these Asian countries, soy products play a role traditional for animal products elsewhere. Each sector of China's large cities has its own soy product factory that uses soybean curd as a base for turning out some 30-40 consumer products. These are rationed, since demand far exceeds supply. In Indonesia, a soy-fungal product, "Tempeh," is sold in a number of different processed forms in every market. Soybean curd "Tofu" plays a significant dietary role in Japan and is even beginning to be found in stores in the U.S. In addition, various forms of textured soy protein, marketed in the U.S. and Europe as meat extenders, are beginning to find their way into Third World markets. For example, they are now popular for rice dishes and soups with plantation workers on the Pacific Coast of Guatemala, who can seldom afford meat.

Soy products for direct human consumption could thus play a comparable role for wheat- and corn-based diets if soy were grown in the right regions, and if the people of these areas become accustomed to processing and eating it. In the humid tropics, to which the soy plant is not currently satisfactorily adapted, other legumes are likely to remain more important. In the more temperate parts of Africa and Latin America, however, introduction of locally processed soy protein products directly into human diets can make a major contribution to meeting protein needs.

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The Role of Soybeans in Food Systems

R. BRESSANI, Institute of Nutrition of Central America and Panama (INCAP), PO Box 1188, Guatemala City, Guatemala, C.A.

ABSTRACT

Technological advances have made it possible to have soybean protein available in various forms: as whole seeds and flours, protein concentrates and protein isolates. These products differ in functional properties as well as in fat and protein content; however, amino acid patterns on a protein basis are essentially the same. Nutritionally, these products have in common a highly digestible protein with ample amounts of lysine and a relatively good essential amino acid pattern. Soybeans have contributed to food systems as sources of calories, as supplementary protein, and as complementary protein because of their good essential amino acid pattern. Furthermore, soybean protein products have made significant contributions to food systems because of their functional properties, which are essential to derive benefit from the nutritional or economic enhancement they impart to other foods. Many examples of this are found in the literature and in practice. Whole soybeans have been used to extend common beans, providing higher energy concentra-