INCAP Publication I-1336

DEVELOPMENTS IN FOOD SCIENCE 2

PROCEEDINGS OF THE FIFTH INTERNATIONAL CONGRESS OF

FOOD SCIENCE AND TECHNOLOGY

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KODANSHA LTD.
Tokyo

ELSEVIER SCIENTIFIC
PUBLISHING COMPANY
Amsterdam-Oxford-New York

1979

1. Exploitation of Food Protein Resources

1.1 An Overview on Protein Sources: Past, Present and Future

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Vegetables in the form of leaves, roots, grain or fruits have always been components of the diet of human populations. However, their significance as sources of nutrients, particularly of protein, was brought into focus some 30–35 years ago, when the world became aware that large groups of people suffered from protein-calorie malnutrition. Such populations, particularly those requiring higher intakes of better quality protein like small children and women, were protein deficient due to a lack of consumption of good quality protein such as that found in animal products. It was recognized that these proteins were too costly for such people.

The concept of utilizing properly combined vegetable protein sources was thus developed. Economic reasons behind the need to supply high quality protein provided the initial momentum to study plant proteins in greater detail, and this has resulted in significant technological advances for the benefit of mankind.

The present paper aims to present an overall assessment of the factors of importance in the production and utilization of protein resources, with emphasis on vegetable sources.

1.1.1 Common Factors in the Production and Utilization of Vegetable Proteins

Within the context of the production and utilization of vegetable proteins in human nutrition, there are a few common factors. These will be discussed first.

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A. Nutritional value of protein

It is well known that protein represents one of the 5 major groups of nutrients necessary for animals, including man. To be efficiently utilized, protein as a nutrient requires the presence of energy, vitamins, minerals and water. Furthermore, the protein must also provide the essential amino acids in the correct amounts and proportions plus some additional non-specific nitrogen. The significance of providing all necessary nutrients is demonstrated in Table 1 based on studies carried out with young swine. Greater performance resulted only when the basic diet was supplemented with energy, vitamins, minerals and the amino acids that limit the protein from corn and beans, as compared to the performance of other partially supplemented groups[1].

Table 1. Weight gain of young pigs fed on corn/bean diets with various supplements alone and combined

Supplement	Corn/bean diet 87/13	Corn/bean diet 70/30
None	2.35 kg	10.88 kg
+ Vitamins	8.50	15.88
+ Minerals	14.63	17.88
+ Calories	6.00	8.63
+ Lys + Try + Met	14.75	13.63
All nutrients	35.00	37.00
Control	54.88	54.88

Animal protein sources display a higher content and more efficient balance of essential amino acids. These and other factors such as a higher digestibility and absence of undesirable nutritional factors endow animal protein sources with a higher nutritional quality. Table 2 summarizes certain results obtained with human subjects[2-9]. The values shown represent the amount of ingested protein necessary for maintenance purposes. Clearly, animal protein sources are superior to vegetable sources, although some of the latter do approach the values of animal sources.

Determination of the efficiency of utilization of protein in man is at present limited by two important questions. One is related to the human requirements for protein or essential amino acids, and the second concerns the evaluation of the quality of protein in foods.

B. Evaluation of protein quality

In recent years, numerous conferences have maintained a continuous discussion of this problem[10]. The primary objective of present methods

TABLE 2. Protein intake from various foods required for maintenance purposes in human subjects

Protein source	Protein intake (g/kg) for N equilibrium	Ref.
Children		
Whole milk	0.52	Viteri & Bressani
Whole egg	0.57	Viteri & Bressani
Cottonseed/corn	0.62	Viteri & Bressani
Soy/corn	0.57	Viteri & Bressani
Sesame	1.13	De Maeyer & Vanderborght
Peanut	1.16	De Maeyer & Vanderborght
Cottonseed	0.91	De Maeyer & Vanderborght
Adult		
Whole milk	0.63	Young & Scrimshaw
Whole milk	0.57	Bressani, *et al.*
Egg	0.42	Inoue, Fujita, Nuyama
Rice	0.51	Inoue, Fujita, Nuyama
Beef	0.64	Young & Scrimshaw
Bean	0.71	Bressani, *et al.*
Soy isolate	0.68–0.71	Young & Scrimshaw
Whole wheat	0.83	Young, Rand, Scrimshaw

TABLE 3. Comparative results of the protein quality of various proteins using a short-term assay and the conventional method

Protein	Protein intake for zero *N* retention (g/kg.day)	
	Conventional†[1] assay	Short term†[2] assay
Soy protein isolate	0.67	0.54
50/50 Beef/soy isolate	0.59	0.57
Beef	0.64	0.53
Milk	0.63	0.62

†[1] MIT.
†[2] INCAP.

such as PER, NPR, NPU, BV, etc., has been to predict the value of a protein sufficient to supply the essential amino acids and nitrogen, thus predicting the amounts required for maintenance and normal growth. Animal bioassay methodology for the measurement of protein quality must be verified in human subjects. Present methods generally require a relatively long time and are of high cost. Recently a short, 9-day bioassay in human subjects has been proposed[5,6]. Comparative results for this short modification and the conventional method are listed in Table 3. They indicate a very good agreement between the two methods as performed in the two different laboratories[5,9].

The main point is that protein utilization needs improved methods for protein quality evaluation. These must be accurate, rapid and inexpensive to be of practical use to plant breeders, the food industry and regulating agencies.

C. Economics of vegetable proteins

From the viewpoint of efficiency of utilization of available resources, including energy, vegetable proteins are produced more efficiently than animal proteins. Based on the amount produced per unit of land, vegetable crops yield from 2 to 9 times as much protein as animals. Besides the production of protein/ha, economic productivity must also incorporate such factors as (1) the number of additional products obtained from a particular source, (2) the potential or actual uses of these additional products, (3) the technological inputs in the production of a product which meets specific functional and organoleptic characteristics, (4) the nutritional aspects of the product, and (5) the process of incorporation of vegetable proteins into food systems. All these factors serve to reduce the economic difference which is apparent between vegetable and animal proteins. Economic nutritional efficiency indices should be made available to guide both manufacturers and consumers. Such assessments should be based on nutrient composition, the protein value of the food including its digestibility and biological value, and cost.

D. Toxic factors in plant proteins

Vegetable protein sources may contain toxic compounds. These can be present in the original material or acquired during storage or processing.

Natural toxic compounds which have received attention include the well-known trypsin inhibitors and hemagglutinin compounds found in food legumes. These groups of foods also contain other toxic compounds, which may be even more active than those just mentioned. Such antiphysiological substances can be eliminated by thermal treatments, as shown in Figure 1 for *Phaseolus vulgaris*, which resulting in an increased animal performance and utilization of the protein.[11] Other natural toxic compounds which have limited the use of vegetable proteins include gossypol in cottonseed, and cyanogens in certain food legumes, nuts, and roots such as cassava and sorghum. Saponins are widely distributed, as are goitrogens.

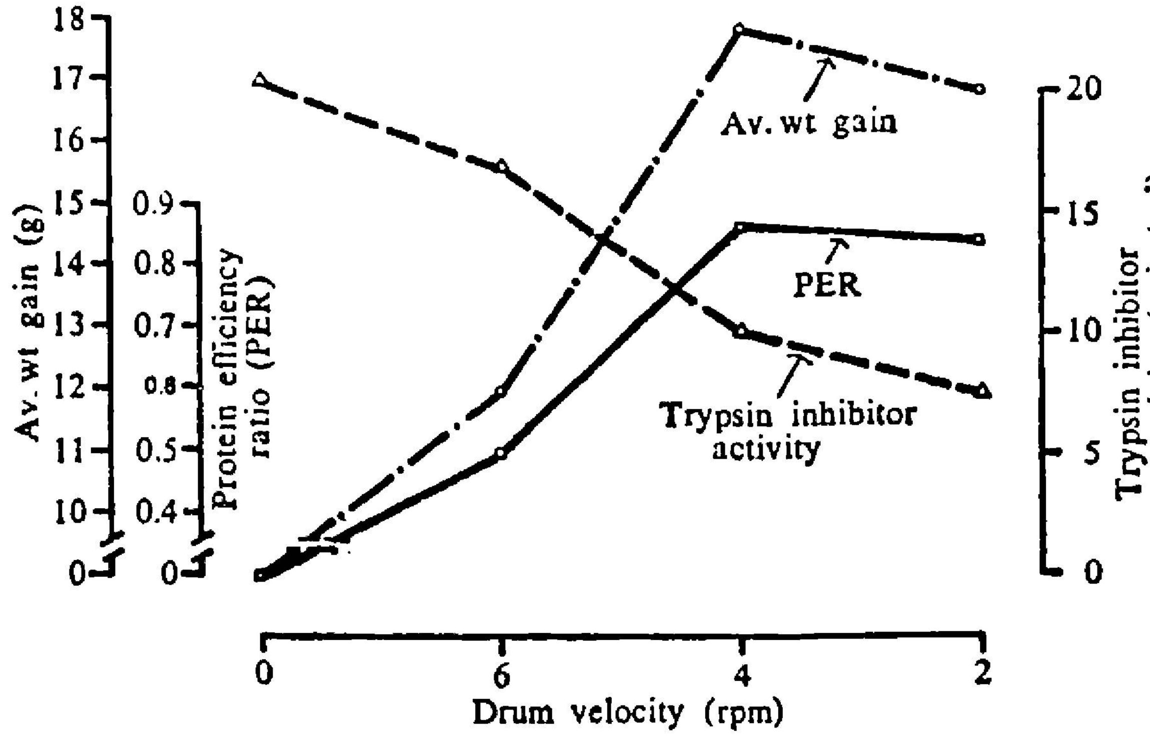

FIG. 1. Effect of heat in the inactivation of trypsin inhibitor activity in *Phaseolus vulgaris* (black coat) (after Bressani *et al.*, 1977).

The naturally occurring toxic substances also include nucleic acids, which tend to limit the potential use of foods in which they are found.

Toxic substances in vegetable protein sources may be acquired after harvesting due to poor storage conditions. Examples include compounds derived from fungal growths. Similarly, insect infestation in addition to the obvious product losses it causes, leads to contamination of food with uric acid, and possibly other undesirable substances. Of similar importance is deterioration of the fat fraction of foods, particularly of those composed of highly unsaturated fatty acids.

Toxic compounds may also develop during processing. One example is the formation of lysinoalanine as a result of the alkaline process used to produce protein isolates. Fat overheating and oxidation may result in the formation of deleterious compounds as well as protein degradation products of protein-carbohydrate complexes, which apart from reducing the quality of the protein, may cause harmful effects on the health of animals. On the basis of the above considerations and if such proteins form an increasing part of the human diet, attention must clearly be given to safety controls. Regulatory agencies must then show concern.

E. Technology for the production and utilization of plant proteins

In the case of oilseeds, processing has previously consisted essentially of removing the oil content to give a product with a higher protein concentration. However, recognition of the loss of protein quality due to extreme heat treatment and the fact that protein quantity can be relatively easily attained by fiber removal, led to the development of newer processing techniques. These are still used for specific protein preparations. Although techniques for other sources have not developed as fast as that for soybeans they are all in principle essentially the same. The newer technology aims to isolate the protein or protein fractions from the source in such a way that materials with desirable physical, chemical and functional characteristics for inclusion in food systems, are obtained.

F. Nutritional aspects of utilization

The nutritional properties should include the protein quality and limiting amino acids so that use in food systems will not result in foods of lower nutritional value. The concentration and isolation of proteins from vege-

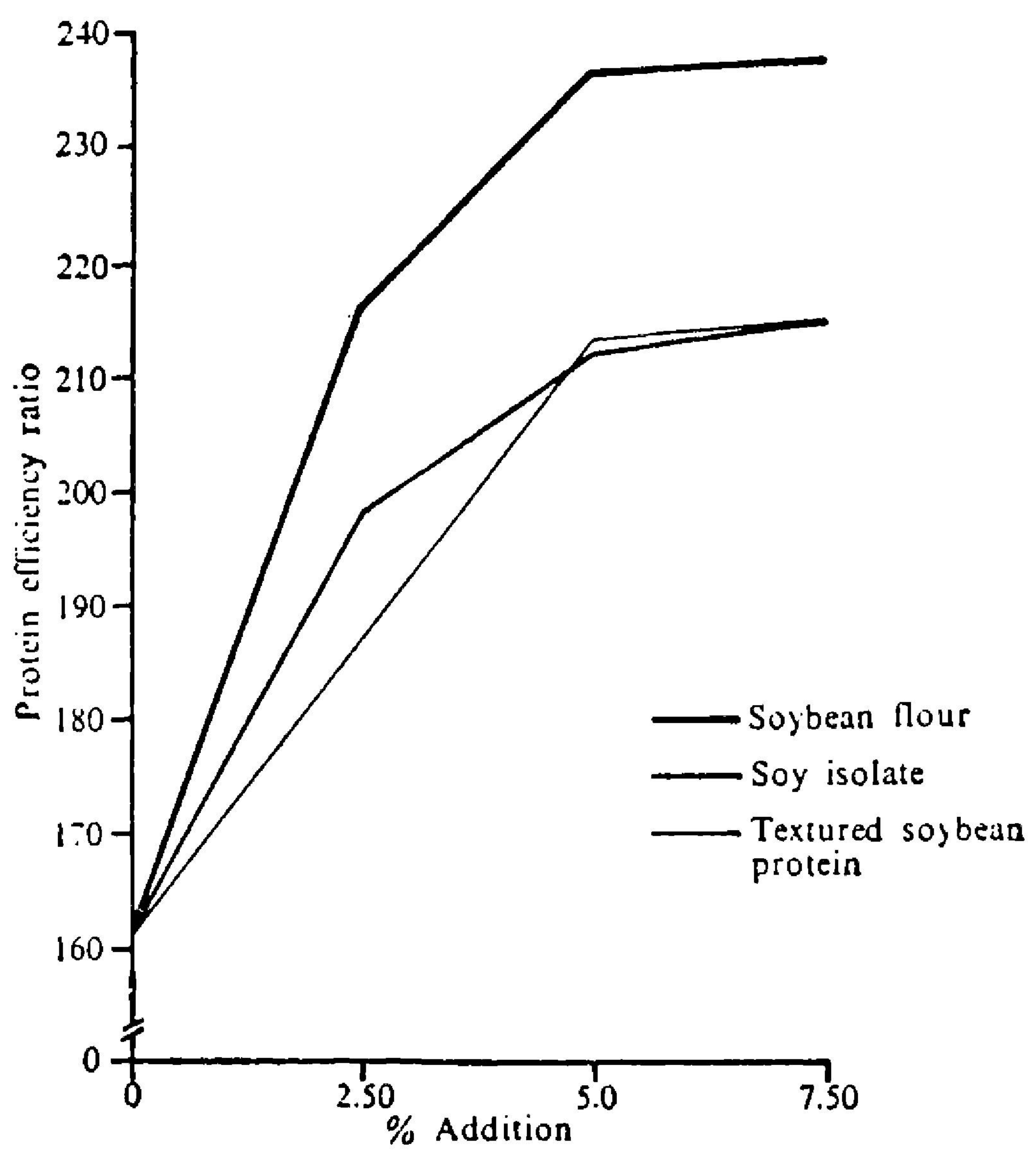

FIG 2. Effect of protein level in 3 soybean products and corn mixtures on the protein efficiency ratio of rats.

table sources in many instances results in products of lower protein quality than the starting material. This may be due to removal of protein fractions with a better amino acid pattern[12]. A second possibility is that antiphysiological factors may be concentrated in the isolated protein[13]. A third possibility concerns the effects of processing conditions *per se* which may decrease amino acid availability. An example is given in Figure 2. In this case, 3 products from soybeans, a flour, a TVP and an isolated protein, were used as supplement to corn. The results indicate that they were not equally effective in improving the protein quality of the final product[14-17].

1.1.2 Sources

Animal protein sources are fewer in number than plant proteins, although insufficient attention has yet been given to small species whose flesh could well be employed in the manufacture of specific types of foods with vegetable proteins. It is important (1) to increase the number of studies on sources and products, (2) to expand the number of applications, and (3) to develop the sources in integrated systems of utilization for the feeding of man and animals.

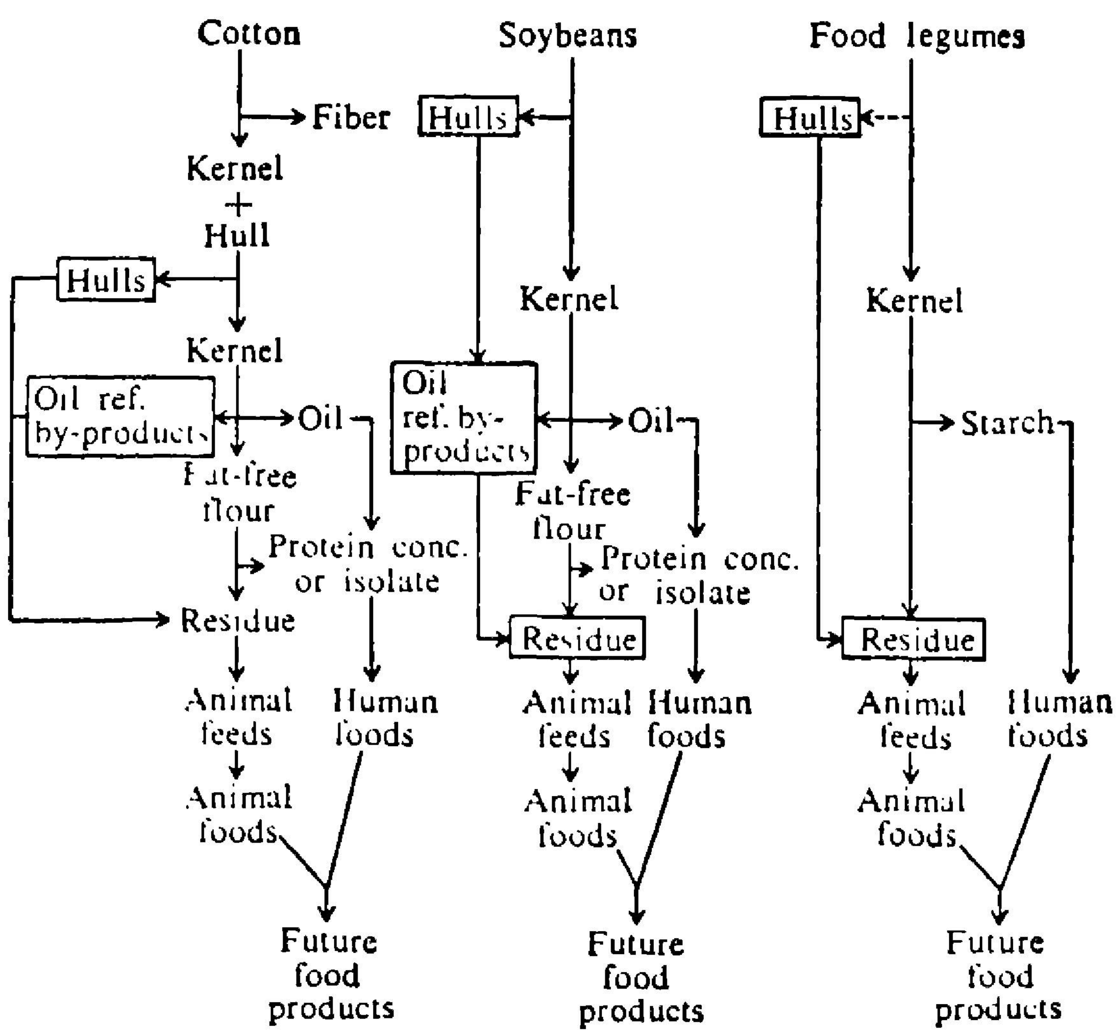

FIG. 3. General uses and products of processing various plant sources.

Many conferences have been held and reviews written on the various plant protein sources. It would appear that in order to increase the number of sources, selection should be based on the basis of protein per ha, as well as on the number of products to be obtained from the source. Various examples are shown in Figure 3.

From this viewpoint, cotton offers more than soybeans, and could, therefore be utilized more efficiently than soybeans in certain areas in terms of an integrated system. Similarly, the selection of legume grains must be based on the value of the starch as compared to the value of the oil from an oilseed. Individually derived systems may of course be combined with others, leading to even more efficient utilization of world resources.

Clearly other factors must also be taken into account, such as the cost of obtaining a product with the desirable characteristics for utilization in various food systems.

1.1.3. APPLICATIONS

The sources of vegetable proteins will depend in part on how diversified its uses are in food systems. Some applications of current and future interest are considered next[16,17].

A. Supplements to cereal-based foods

Examples include the addition of 8–15% soy protein to corn and the addition of similar amounts to wheat flour, resulting in products of higher protein content and quality.

B. Animal protein extenders

The major application of interest at present is to use the products as animal protein extenders. Such replacement, however, must not decrease the nutritional value of the original product. Representative results are given above in Table 3 for beef, TVP and a 50/50 mixture of beef TVP. The quality of the mixture is as good as that of beef. Most of the studies so far carried out have concerned the monitoring of protein quality. However, the part of the food these extenders replace provides more than protein: energy, minerals and vitamins are also supplied. The use of extenders in meat products is expected to expand rapidly in the future, both in developed and developing countries.

C. Milk extenders

Due to their specific functional properties, some vegetable proteins produced by various techniques can also extend other foods such as milk and even foods derived from milk. This kind of application is more likely to be developed in areas of the world where milk production is not keeping pace with demand. However, due to the high quality of milk proteins, the danger of decreasing quality by extending them with protein isolates is high.

D. Meat analogues

An additional application which is likely to expand in the future is the production of meat analogues. Since vegetable proteins are lower in quality than animal proteins, meat analogues may also be of inferior quality. However, two other factors may be of importance in this respect. One is that various proteins may be selected for spinning without differences in final texture. Secondly, if various proteins can be used, these may be combined so as to compensate for deficiencies in protein quality which arise from the use of only a single source. These factors must be emphasized since success in the utilization of such products will depend to a great extent on their nutritive value.

In conclusion, it can be said that the problem in all the above applications is the dependence on one source such as soybeans. Efforts must therefore be made to develop other sources. Indeed, such work is now being carried out with rapeseed, green leaves, legume grains and single cell proteins. It is believed that as direct or indirect economic pressures increase, they will stimulate increased research, and significant advances in the development of products from vegetable sources will follow. By-products of these developments will be increasingly used as feeds for animals, the products of which, when properly combined with those derived from the vegetable kingdom, will feed man in the future.

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