Soy Proteins in Foods—Retrospect and Prospect

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ABSTRACT

The soybean has been used for food in the Orient for centuries, but the western world has been slow to adopt it. In the last 40 years soybeans have become an important source of protein in poultry and livestock feed. In the last 10 years or so it has been used in foods in increasing amounts to supply low cost high quality protein with important functional properties. The soybean will be vital to meeting the protein needs of the future in all parts of the world, especially in the developing countries. The challenge is great to the plant breeders and agronomists to improve yields and adaptability of the crop and to the soy technologists to improve the characteristics of processed soybean proteins.

RETROSPECT

Historical Introduction

A native crop of eastern Asia, the soybean has served there as an important part of the human diet for centuries. For example, in Japan, some 12-13% dietary protein is derived from soybean products.

In the western world, food uses of soybeans have followed a different pattern from those of the Orient. Only grown in quantity since the 1920's, interest rested in the production of soybean oil for use in the manufacture of such products as margarine, cooking oil, shortenings, mayonnaise, etc. Recognized even then for its high protein content of good nutritional value, the defatted meal was used primarily for animal feed. At the time this represented a complete economic pattern of use so much so that the defatted meal was never regarded as a by-product, i.e. it was recognized as a full economic entity in its own right.

Over the last 30 years production of soybeans in the U.S. has expanded from a minor commodity to a major cash crop. Only within the last 10 years, however, have many edible products been associated directly with their soybean source. There are several reasons for this anonymity, largely based upon prejudice against an unfamiliar product, but also linked to problems of flavor and flavor stability, the function of soy products in foods and their physiological effects—problems which today are largely overcome by advances in modern processing technology.

Constitution of the Soybean

Botanical constitution: The soybean (*Glycine max*) is a typical legume seed differing in color, size, and shape, depending upon variety. The common field varieties grown in the U.S. are nearly spherical and are yellow in color, e.g. the Lincoln soybean. The food reserves of the seed are stored in the cotyledons (90% seed), the interior of which is filled with elongated pallisade-like cells themselves filled with protein and oil. The bulk of the protein is stored in protein bodies varying between 2μ and 20μ in diameter. The oil is located in smaller structures, the spherosomes, 0.2μ-0.5μ, interspersed between the protein bodies. Isolated protein bodies may contain as much as 90% protein and together account for 60-70% total protein of defatted flour.

Biochemical constitution: Proximate analysis of the whole bean shows that protein (40%) and oil (21%) make up ca. 60% bean, the remaining third consisting of nonstarchy carbohydrates, including polysaccharides, stachyose (3.8%), raffinose (1.1%), and sucrose. Nucleic acids are present only as minor constituents of the soybean, unlike some of the new single cell protein sources where nucleic acids can account for between 5% and 20% cell wt and may be included within the total nitrogen analysis without contributing to the protein or nutritional value of the isolate.

Other minor constituents, such as the antitrypsin factor and so called "beany flavor" components, have caused adverse comment against the use of soybean products in the human dietary. Moreover, every legume, beans, peas, the field bean, also has the flatus problem; but, as we shall see, all these problems are superable through a better understanding of the causes and the development of an improved technology capable of supplying completely bland soy products high in valuable protein at a fraction of the cost of equivalent proteins. In fact, today, soy protein may be said to be available in forms freer from unwanted contamination than many other vegetable proteins, including cotton seed meal, containing gossypol, or rape seed in which erucic acid may remain. Even concern over antitrypsin factor in soy products for human consumption may be misplaced in view of recent findings (1,2), which suggest that legume trypsin inhibitors may not be physiologically active in man.

Nutritional Aspects

The importance of soy protein in nutrition lies in its

TABLE I

Mg/g Total Essential Amino Acids

Amino acid	Defatted soy flour	Wheat flour	*Aspergillus niger*	Egg protein
Isoleucine	119	116	106	129
Leucine	181	195	172	172
Lysine	161	82	118	125
Phenylalanine	117	140	154	114
Tyrosine	91	97	88	81
(Total aromatic amino acids)	(208)	(237)	(242)	(195)
Cystine	37	64	16	46
Methionine	37	49	64	61
(Total sulphur amino acids)	(74)	(113)	(80)	(107)
Threonine	101	88	96	99
Tryptophan	30	40	---	31
Valine	126	131	184	141

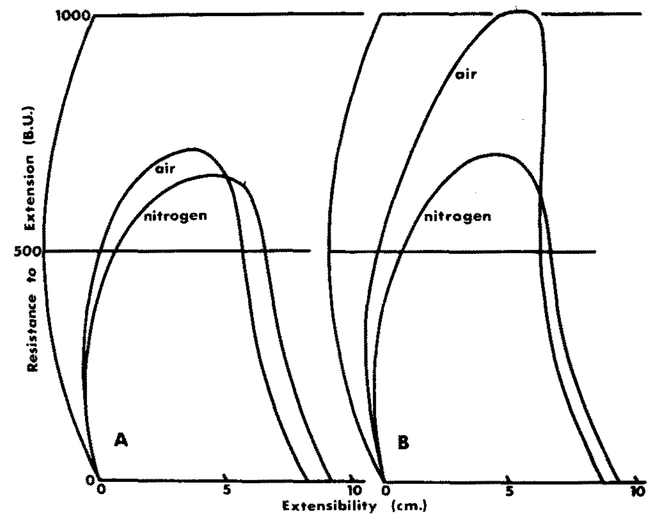

FIG. 1. Coupled oxidation of dough protein.

high content of essential amino acids, particularly lysine, leucine, and isoleucine. Table I compares the levels of essential amino acids in the protein of defatted soy flour with those in wheat, egg, and single cell protein. The superiority of soy protein in respect to these amino acids is demonstrated clearly in the table. Thus, in animal foods, cereal proteins low in lysine, e.g. wheat, can be blended with soy proteins to make feeds which are better protein sources than either protein by itself (2). The table also shows that only in the sulphur containing amino acids, cystine and methionine, is the soybean low, indicating that methionine is the first limiting amino acid to be considered when using soy products in a diet.

Full fat soy flour also offers a valuable nutritional contribution from the high proportion of essential fatty acids, linoleic (51%) and linolenic (9%), that its oil contains. Since the oil represents some 20% total flour, the use of soy flour as a supplement in high protein breads (e.g. Cambridge Formula) also elevates the essential fatty acid content of the product.

The importance of heat treatment in soybean processing must not be underestimated. Careful control is required as overheating may give less than the optimum nutritional value. The relationship between heat treatment and nutritional value is shown in Table II. It is seen that the relative protein efficiency of defatted soybean flour can be raised to 90% of that of dried skim milk by correct toasting.

TABLE II

Nutritive Value of Defatted Soy Flour

Heat treatment	Relative protein efficiency[a]
Negligible	40-50
Light	50-60
Moderate	75-80
Toasting	85-90

[a]Dried skim milk represents 100% efficiency.

TABLE IV

Nutritional Yields/Acre[a]

1	acre	Soybeans	will	sustain	a	man	for	2224	days
1	acre	Wheat	will	sustain	a	man	for	877	days
1	acre	Corn	will	sustain	a	man	for	354	days
1	acre	Beef	will	sustain	a	man	for	77	days

[a]See ref. 5.

Retrospective Conclusions

One may conclude, in retrospect, that the western world has been slow to make use of a product more valuable on economic, technical, and nutritional grounds than its recognition in the human dietary would suggest. Bad marketing, poor presentation, and the persistence of prejudice have all contributed, not least the bad reputation derived from the use of soy based marzipan substitutes introduced in the U.K. during World War II.

Even in the field of bread technology where enzyme active soy flour can contribute to loaf color, water absorption, and, as we now understand from work at Spillers R.T.C., Cambridge, England, gluten development and shortening function, the industry has been shy to adopt soy products on a wide basis. The remarkable effect of soy lipoxygenase in preventing the loss of added shortening fat through binding to the dough protein during mixing is shown in Table III. Where enzyme action was prevented, as much as 80% dough fat phase was bound during mixing. While this was reduced by the addition of linoleic acid as substrate for the limited amount of flour lipoxygenase present, the further addition of the soy enzyme reduced by more than half the protein binding of fat to 36% total. Further work at Cambridge has shown that this effect of soy enzymes on the fat is accompanied by a coupled oxidation of the dough protein (Fig. 1) resulting in increased gluten strength (4) and improved baking performance (Fig. 2), as shown by improved volume and loaf softness. Such observations already are contributing to our understanding of the action of the new soy based improvers in the baking industry, leading to a wider acceptance of the benefits offered by these innovations. Let us, then turn to the prospects ahead for the soybean and focus attention on the need to avoid the mistakes of the past.

PROSPECTS

Technical Prospects

Continuing use for established products: Full fat soy flours will persist as supplements in food products and as ingredients offering technical advantages in food processes on the basis of their rheological and enzymic properties. Pet foods, animal feeds, and bakery products will all require the continuing use of full fat soy products as energy sources, emulsifiers, and texture improvers. The reduction in friability of meat loaves by adding full fat soy flour is well recognized in the U.K.

In meat technology, soy concentrates containing up to 70% protein and isolates of 90-95% protein are already well established as aids in the production of high quality meat

TABLE III

Effect of Soy Lipoxygenase on Shortening Fat Binding[a]

Shortening	Bound lipid (% total)	
	No soy enzyme	Soy enzyme added
Shortening fat alone (no substrate)	81.0	80.0
Shortening plus 5% linoleic acid	66.5	36.2

[a]See ref. 3.

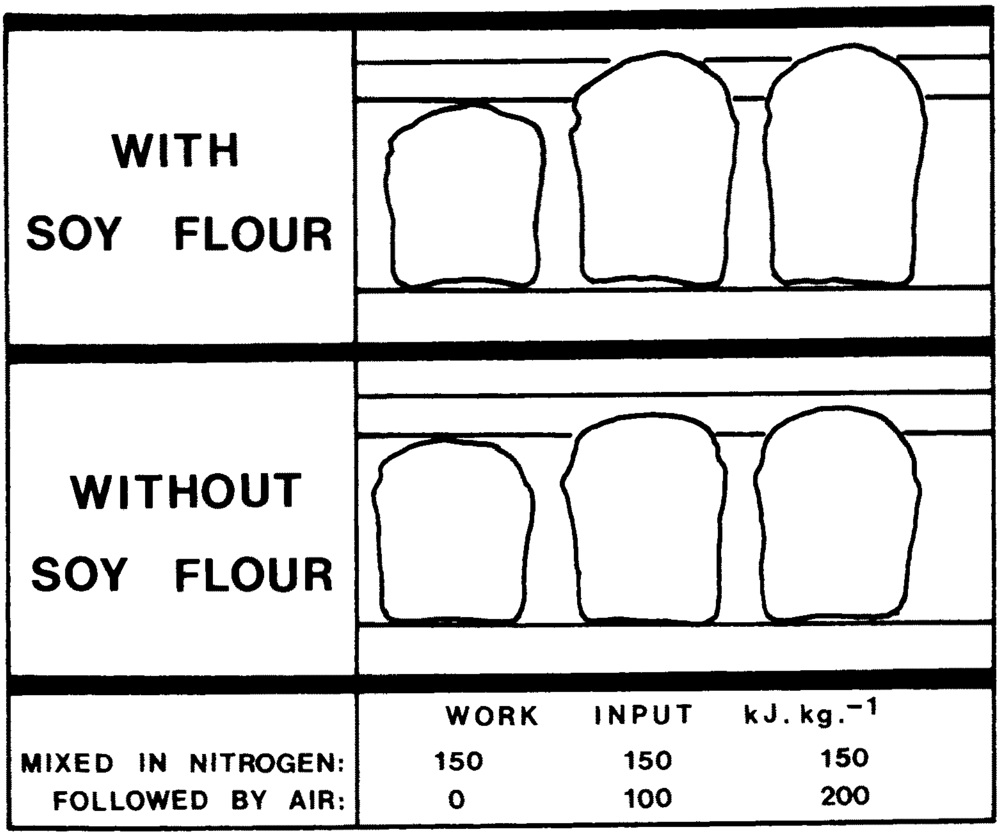

FIG. 2. Improved baking performance.

based products. Here, soy proteins offer valuable emulsifying and stabilizing properties useful in products such as sausages and meat pies, where they help to improve the binding of the meat structure, as well as reduce losses of water and fat from the product during storage and cooking.

A major obstacle to be overcome is still that of flavor. While the problem has been reduced through the development of bland soy protein isolates, such products are expensive and at present represent only a small part of soy utilization. The problem of beany flavor still remains in areas using concentrates or simply straight defatted soy flour. For example, further research is required on methods to remove residual beany notes from texturized soy proteins (TSP) by improved processing or flavor masking. More work also is required by the creative flavorist to develop fully acceptable and stable flavored soy protein products, particularly in the area of meat analogues. In this area, soy protein hydrolysates already have an established usage as a meat flavor source material, a use that may well expand as world meat prices rise.

In the context of human and animal nutrition seen against an increasing demand for meat protein, soy represents, at present, the only consistent and abundant vegetable protein resource available for food and animal feed purposes. Backed by a well established technology, established soy products are standarized and predictable in quality both functionally and nutritionally and will continue to be used profitably in the future as they have in the past.

Further development of novel proteins: Already established as a viable addition to human nutrition, novel proteins from soy beans are backed by a more comprehensive background of technological research than any other vegetable protein. Today, in the U.K., the expansion in usage of TSP is held back more by the Trade Descriptions Act than by any other technological deficiencies or shortcomings. In the U.S., this has been overcome by the use of such labeling as "food X with TSP" or "food Y with added protein." Thus, TSP is made attractive to the consumer in its own right.

Meat analogues based on soy protein are most likely to be used in the immediate future as meat extenders in the U.K. in the same way that their usage is growing in the U.S. Two options are open in this area: (A.) as an addition to increase the intrinsic nutritive value of a food and to confer new functional properties, thereby aiding the development of novel premium products; and (B.) as a replacement for part of the meat in traditional products where new names will be used to conform with the labeling regulations of individual countries.

The range of applications of soy protein as meat extenders is limited only by the ingenuity of the chef. It would be unfair to regard these soy products as ersatz. These are new foodstuffs which may be very similar to meat and which are already being used in such products as hamburgers, sausages, veal and ham pies, and with comminuted meats generally. Further uses are found in brawn, paté, soups, and sauces, including curry and spaghetti bolognase. An example of the versatile functional nature of TSP is its use in fruit pies to improve the texture and quality of the product.

In the long term it seems likely that TSP will emerge as a basic food product in its own right. This will depend upon the soy technologists overcoming such problems as those concerning the coloring and flavoring of this product, so that leaching and processing losses are avoided. The functional properties of soy protein will receive further attention both in the preparation of milk and egg protein substitutes and in the development of new food formulations. Here, spun proteins represent an exciting opportunity for the development of meat analogues, where, in addition to color and flavor, nutritionally required supplements, including minerals, vitamins, and fats, can be incorporated between the fibrils together with binding proteins, such as egg albumen, also help to promote a favorable amino acid balance. Acceptance of spun and texturized soy protein in the world food markets is increasing daily and may be the only way in which the current excessive demands, presently being made on western meat resources, will be alleviated.

Nutritional Prospects

As our understanding of the requirements for correct protein balance in human nutrition increases, so does our realization of the highly nutritious properties of soy protein, particularly when compared with other available sources, such as single cell protein, cotton seed, and field bean. In combination with other cereal grains and backed by proper processing, soy protein offers the only expanding commercial source of protein able to meet the growing demand for a nutritionally balanced, high protein food suitable for both human and animal feeding.

Toxicologically, soy products have a long history of acceptability, free from such problems as contamination from mold toxins found, for example, in more difficult crops, including the peanut. The yield/acre in nutritional terms is also highly favorable to soy bean in the context of meeting the nutritional demands of the ever growing world population. This is calculated as expanding at a rate of 6,000/hr, requiring an extra 2 1/2 sq miles of intensively cultivated land to provide necessary food. Table IV shows the nutritional efficiency of soybean compared with other protein sources in making use of available land for food production.

Economic Prospects

On a price basis, soy products stand alone as the most economical source of food protein available in commercial quantities today. Pressures on animal protein supplies increase continually and, as John Hawthorn recently observed, do so at the continued expense of our nonrenewable reserves of fossil fuels, indispensible for the methods of intensive agriculture required to sustain supplies. Thus, production of high yielding soybean protein through a photosynthetic process, which places fewer demands on our energy reserves, must become increasingly attractive economically. Further research into new varieties of soybeans capable of growing commercially in more temperate regions will lead to increased cropping thereby alleviating transport cost problems and availability. The long history of accepted use of soy products in food also removes all need for expensive toxicological testing as is required for novel proteins derived from mold or bacterial sources.

Political Aspects

Finally, but by no means least, there are the politics of world protein needs already pointing to the extravagant and growing demand for animal protein in the affluent countries. Max Milner already has spotlighted the anomaly that demand for increased meat protein consumption comes most pressingly from those societies already consuming far more than they need either for good nutrition or good health. Conversely, protein consumption may even decrease in those societies already suffering from protein malnutrition.

The situation has been worsened by the recent crop failures of the so called "green revolution" in recent years, due to adverse weather conditions in Asia and India. Here, the shift in emphasis to new cereals, such as Triticale, at the expense of traditional crops has worsened rather than improved food supplies. In the long term major increases in world food production will have to arise within the developing countries rather than from increased assistance from affluent societies.

On a global basis it is the distribution, economically, of world food resources that will demand change. Here, fish, meat, cereal, and legume resources will be scrutinized to ensure fair and adequate distribution. A consequence must be that patterns of nutrition will change and that economic pressures inevitably will reduce western utilization of meat, at least on a per capita basis rather than overall, where usage will still increase to meet rising demands. To the individual—you and me—this will mean that our meat intake will fall and almost inevitably be replaced by vegetable protein. Here, consideration of all aspects, including economic and agronomic, leads to the conclusion that soy protein is the protein of the future, with the proviso that the food technologist rises fully to the challenge of making his product palatable and, therefore, widely acceptable.

Finally the plant breeder must make the soy plant more versatile, more capable of growing in temperate climates and, if possible, make it grow successfully in warm climates but in soils often short of water. If man can grow vines and the tobacco plant, as he can in volcanic lava, utilizing the absorption of night moisture, surely he can devise a soy variety which will do the same. This will be a tremendous step forward in helping both developing and developed countries who have problems of little rainfall.

With all the possibilities mentioned in this introduction to our Conference, surely the keynote is—Sic gloriate Soya!

REFERENCES

1. Coan, M.H., and J. Travis, PAG Bull. III. 2:1 (1971).
2. Wilding, M.D., Cer. Chem. 45:254 (1968).
3. Daniels, N.W.R., Bakers Digest 4:20 (1971).
4. Frazier, P.J., J. Sci. Fr. Agric. 24:421 (1973).
5. Bean, FAO Bull. (Rome) 6 (1966).