DEVELOPMENT OF NEW HIGHLY NUTRITIOUS FOOD PRODUCTS

R. Bressani
and
L. G. Elias

TABLE OF CONTENTS

INTRODUCTION

Much interest has evolved on the subject of developing highly nutritious food products during the last decade, due to various reasons, among which the most important probably is the prevention of a nutrition crisis in developed and developing countries alike It is well known that the nutrition problem is more acute in developing areas because of a constantly increasing population without parallel increases in food production Furthermore, within the population of the developing countries, foods for the most vulnerable groups, such as weaning and pre-school children and pregnant women, require more attention, because such groups require foods with higher concentration of nutrients in the appropriate balance, for higher nutritional quality

Among nutrients, one which has received particular attention is protein which, even if available in relatively large amounts, is not evenly distributed among the population within areas, with some getting foods of higher protein content than others

Total protein is only part of the problem, more important is protein quality, that is, the concentration and balance of the essential amino acids in the protein The usual protein foods which generally provide the needed protein quality in developed countries are milk, meat, and eggs These foods are not easily obtained by the low socioeconomic groups in developing countries because of their low availability, high cost, and lack of appropriate transportation and storage facilities

Although the quantity and quality of the nutrient, protein, have probably received more attention, nutritional and dietetic surveys have pointed out that other nutrients are also lacking in the diets of most people These are vitamin A, riboflavin, and probably, iron In particular cases, other nutrients can also be lacking, for example, niacin, vitamin D, calcium, iodine, ascorbic acid, and thiamine

In view of the above, the development of highly nutritious foods can be a rather complex problem in which consideration must be given to the nutritional limitations of the food itself, as well as consideration of its role as a carrier of nutrients in relation to other foods consumed, the methods or ways in which it is prepared for consumption, nutrient requirements by specific population groups, stability of nutrients, economic and acceptability aspects, and many other points as well The problem will not be solved by one group of scientists, but by all directly or indirectly concerned with foods, from the agronomist to the marketing specialist However, a very important role is played by food scientists, technologists, and nutritionists, who are responsible for formulating such new or highly nutritious foods in terms of nutrient content, preservation during processing, and high standards of acceptability.

For efficient utilization of specific nutrients in a particular food, which is the principal aim of developing highly nutritious foods, consideration must be given to all nutrients which could be lacking in the food or diets For example, little is accomplished by improving only protein quality if vitamins or minerals are also deficient The present chapter summarizes some of the information available on the problem of the development of highly nutritious products, starting from the available nutrient sources, the objectives in developing highly nutritious foods, and the applications in terms of technologies at our disposal to provide mankind with highly nutritive and efficiently utilized food products.

AVAILABLE SOURCES

Animal and vegetable foods have been recognized through history to be the main sources of nutrients for mankind. However, as the world population increases, the supply of foods is becoming a crucial problem since food production has not increased in proportion to the growth of the population. The problem is even more serious in those areas of the world labeled underdeveloped, since in this case the challenge is not only to eliminate the shortage of foods, but also to improve their nutritional quality. In other words, this implies the utilization of the available resources with the highest degree of efficiency. On the other hand, it seems that among nutrients, the lack of protein ranks first, followed by calories, vitamins, and minerals Unfortunately, meat, eggs, milk, and fish, considered to be the best natural sources of good quality protein, are either in short supply or expensive in the developing areas of the world. In general, vegetable sources such as cereals, legumes, oilseeds, and starchy roots constitute the main source of nutrients for those people. Such food commodities are considered to be of a relatively low nutritive value, as compared to the animal sources. However, the technology of this century has permitted the chemical and biological synthesis of many nutrients, such as amino acids and vitamins, that can be used to improve the nutritive value of many foods. From these introductory remarks, it can be concluded that the available food sources in this situation must be confined mainly to vegetable staple foods, to nonconventional sources, and to nutritional additives.

Vegetable Sources

Cereals

In general, this group of foods has low protein quantity and quality, lysine, tryptophan, and threonine being the most limiting amino acids. From the nutritional point of view, they must be regarded mainly as sources of calories, although this is not entirely true in practice due to their high intake which provides significant amounts of protein and of other nutrients.

Because they are bulky and low in protein, it is rather difficult to obtain an adequate protein intake with them.

Legumes

Leguminous seeds can be considered as natural supplements to cereals, since they contain adequate amounts of lysine;[2] they are generally deficient in the sulfur-containing amino acids,[3,4] which are in turn present in adequate levels in cereals. Another limitation is their low protein digestibility in many species and varieties[5,6] and the presence of adverse heat-labile physiological factors. However, these difficulties can be overcome by processing methods involving heat.[7] The antiphysiological factors can also be removed by protein extraction, giving products that can be useful in many preparations. Since legume foods have at least twice the protein content of cereals,[1] they can contribute significantly to the solution of the problem of protein quantity.

Starchy Roots and Tubers

As a source of nutrients, these groups of foods must be considered only as a source of calories; their protein content is very low,[8] although it must be recognized that potatoes, for example, have an attractive amino acid pattern.[9] Cassava roots have also been reported as a good source of calcium.[10]

Nonconventional Foods

Oilseeds

This group of resources can be considered as one of the best sources of both protein and calories. Their economic and nutritional properties constitute a valuable asset in the formulation of high nutritive foods.[1,11] The press cake left after oil extraction is a product with about five times more protein than the cereals and twice the amount present in the *Leguminosae* seed. The protein content can be further increased either by screening techniques, which separate the fiber,[12] or by precipitation of the protein after its extraction with adequate solvents.[13,14] In addition, they are relatively high sources of some essential amino acids, as for example, lysine and tryptophan in soybeans,[15-17] and methionine in both cottonseed,[11,18-21] and sesame protein.[16,22,23]

The presence of toxic factors in the oilseeds, such as gossypol in cottonseed[11] or trypsin inhibitors in soybeans,[24] can now be eliminated through appropriate processing techniques.[11,25] Soybeans can be considered as an exception in the group of oilseeds since they cannot be classified as a nonconventional food; their use as a natural source of nutrients in the Orient, mainly in the form of fermented foods,[26] is well known.

Palm Kernel and Nuts

This group must be regarded mainly as a source of calories or of essential fatty acids. Protein content can be increased either by oil extraction or by fiber removal. According to the particular product, it seems that lysine, methionine, and tryptophan are the most limiting amino acids.[27,28] More technological research and an increased availability must be attained in order to utilize them as a source of proteins.

Leaf and Algae Protein

The main drawback in the utilization of these materials as a source of protein has been from the economic and organoleptic points of view. The amino acid compositions indicate that the sulfur-containing amino acids are the most limiting in both cases.[29,30] In general, it can be said that they have a relatively good nutritive value, their low digestibility in some cases being their most important limitation.[31]

Yeast and Microbial Proteins

From the results of several studies,[1] it can be concluded that food yeasts (*Torulopsis utilis*) and brewers yeast should be good sources of proteins and vitamins of the B complex. Being rich sources of lysine with a protein content between 40 and 50% and also rich in vitamins, they are suitable materials to supplement many foods.[32,33] The main disadvantages of these products are a relatively high cost of production, the limited acceptability in human diets, and a high nucleic acid content.

The use of other microorganisms, mainly as a source of proteins and vitamins, should be encouraged. It is important to mention that some bacteria are able to synthetize vitamin B_{12}, which is not found in vegetable food sources.

Nutrients

Additional sources now available to improve the nutritive value of foods include some synthetic nutrients which can be used for the purpose of supplementation, enrichment, or fortification. They can be classified in three general groups; namely, amino acids, vitamins, and mineral salts.

Amino Acids

Among the amino acids, lysine and methionine are now available at a relatively low cost, permitting practical usage. Tryptophan and threonine, however, are not commercially available at a reasonable cost.

Vitamins

These important nutrients are now available commercially and are used in many instances to fortify different kinds of foods.

Mineral Salts

The most widely used mineral salts are iodine, iron, calcium, and phosphorus, in the form of their salts. These nutrients, together with the vitamins, play an important role in the efficient utilization of foods.

OBJECTIVES OF THE DEVELOPMENT OF HIGHLY NUTRITIOUS FOODS

The purpose of developing highly nutritious foods is probably different in technically advanced countries than in developing areas of the world. Since food is highly available and of greater variety in the developed countries, attention will be given here to foods already consumed in the latter areas which need nutritive quality improvement and to foods which are needed to supply the required nutrients for these populations because of the low availability and variety of the better quality foods of animal origin.

A highly nutritious food could be defined as one which is utilized by the animal organism with a minimum of waste, alone or with other foods, providing adequate amounts of the nutrients needed to meet the demands for the physiological functions of the organism. Therefore, the development of highly nutritious foods implies the improvement of the food not only in its protein component, but in the vitamin and mineral aspects of the food or diet as well. Of the three groups of nutrients, the protein component of the food probably represents the most difficult to correct when it is necessary to achieve high nutritious quality. This characteristic is best expressed as biological value, a figure which represents the amount of nitrogen absorbed which is retained by the organism to meet physiological demands.[34]

The biological value of the protein is determined by the essential amino acid content of the protein, which must be present in the correct balance[35] and in the appropriate proportions[35] for maximum and efficient utilization. These concepts have not been appreciated fully, and as a result, there is a great waste of nitrogen.

Improvement of the biological value of a protein must be carried out following the well-established concept of limiting amino acids. Consequently, the first limiting amino acid should be added in such concentration that the total amount of it in the food protein balances with that of the second limiting, as well as with other amino acids, according to the needs of the organism. This improvement can be brought about by different means; by adding protein, by adding the limiting amino acids, or by adding the correct mixture of the two.

As indicated above, the objective in developing high quality foods with respect to protein is to utilize protein efficiently, that is, with a minimum of waste. Even though higher intakes of protein may result in an appropriate intake of the essential amino acids, this is obtained at the expense of great waste, even if the organism is growing in apparently good nutrition (see Table 1). Results of

TABLE 1

Comparison Between the Protein Value and Amino Acid Intake of Opaque-2 and Normal Maize

	Opaque-2		Normal	
Maize intake to obtain nitrogen equilibrium, g/day	250*		547**	
Protein intake, g/day	27.9		43.8	
Biologic value of protein, %	82***		46.5**	
Protein retained, g	23		21	
Protein wasted	5		23	
Amino acid in protein retained	g/16 g N	% total EA int	g/16 g N	% total EA int
Isoleucine	1.01	8.63	2.00	10.53
Leucine	2.70	23.08	5.60	29.49
Lysine	1.34	11.45	1.25	6.58
Methionine	0.60	5.13	0.80	4.21
Cystine	0.55	4.70	0.56	2.95
Phenylalanine	1.33	11.37	1.96	10.32
Tyrosine	1.14	9.74	2.64	13.90
Threonine	1.10	9.40	1.72	9.06
Tryptophan	0.39	3.33	0.26	1.37
Valine	1.54	13.16	2.20	11.58
Total essential amino acids	11.70		18.99	

*(From Clark, H. E. et al., *Am. J. Clin. Nutr.*, 20, 825, 1967. With permission.)
**(From Kies, C. E. et al., *J. Nutr.*, 86, 350, 1965. With permission.)
***(From Young, V. R. et al., *J. Nutr.*, 101, 1479, 1971. With permission.)

Clark et al.[36] and Kies et al.[37] have shown that 250 g of Opaque-2 corn are sufficient for nitrogen equilibrium in adult humans, while 547 g of common corn are needed.

Assuming the same protein percentage in both foods, 27.9 g are ingested from Opaque-2 corn, while 43.8 g are ingested from common corn. Using a biological value of 82%[38] for Opaque-2 corn, about 23 g are retained of the 28 g protein ingested. This amount is similar to the amount of protein retained from common corn, around 21 g, with a biological value of 46.5%.[39] These figures indicate the great loss of nitrogen in common corn which is deficient in the essential amino acids, lysine and tryptophan,[39] and has a poor essential amino acid pattern. The loss of nitrogen from common maize amounts to 23 g, in contrast to 5 g lost from Opaque-2 maize. The respective essential amino acid intake is also shown in Table 1. These figures indicate that, with the exception of lysine and tryptophan, common corn provides greater intakes of other essential amino acids, which represent a load the body must eliminate contributing to the waste. These figures show that the amino acids absorbed are out of balance which further explains the poor biological value of common corn protein. The poor balance of essential amino acids is more obvious when amino acid intake is expressed as the percentage of the total essential amino acids ingested. This manner of expressing the values increases the deficiencies of lysine and tryptophan and magnifies the excesses of the other amino acids.

Protein quality is just one aspect of highly nutritious foods; other nutrients are also needed. This is emphasized by the results to be presented in proceeding sections (Table 8). They indicate that in order to obtain an improvement in protein quality through the addition of the two limiting amino acids of the maize-bean diet, vitamins and minerals are also required.[40]

APPLICATIONS

High Protein-containing Foods

High protein-containing foods were and are being developed throughout the world to meet the specific need for protein quality and quantity for population groups able to consume the usual high protein foods, such as milk, meat, and eggs. These high protein foods have been developed by combining, either from amino acid values or from the results of biological assays, various sources of proteins in such a way as to achieve higher concentration of protein as well as higher quality.[1,41–46]

In many cases, the ingredients used are exclusively of vegetable origin, and in others, variable amounts of animal protein sources, mainly milk powder or fish protein concentrate, have been included in the formulation. In such cases, the purpose has been to enhance protein quality as well as to indicate to the consumer that such foods contain animal food products, usually associated with good nutrition. The enhancement in protein quality can also be achieved by the addition of small amounts of synthetic amino acids.[35] The improvement in protein quality is necessary, particularly when the high protein food is made of vegetable protein sources which, as has already been indicated, have essential amino acid deficiencies even after various sources have been blended.

The high protein-containing foods with improved protein quality have been developed to be used as weaning foods or as protein supplements to low quantity and quality diets.[47,48] Although they provide good protein nutrition to people of all ages, they have been aimed at those population groups more susceptible to protein malnutrition; the weaning child, pre-school children, and pregnant and lactating mothers. The majority of these foods contain over 17% and up to 27.5% protein, with a protein efficiency ratio above 2.2. Many have been evaluated for their protein quality in biological assays with experimental animals and/or human subjects.[42,48,49] Some results, shown in Table 2, indicate that they are of a high protein quality in both species.

Table 3 summarizes some additional information on a few high protein foods. Observations of the ingredients show that most formulations are based on oilseed flours of a low fat content. These flours have been processed under well-controlled conditions to preserve the protein quality of the product. In some cases, the vegetable protein source utilized has been further processed to a higher concentration than the usual 50% commonly found in the oilseed flour. In some cases, flavoring agents have been added, while in others, they have been eliminated due to cost considerations, dietary habits, or preservation facilities. As previously indicated, some formulations contain small amounts of animal protein sources or essential amino acids. In most cases, the formulations have been supplemented with the vitamins

TABLE 2

Protein Quality of Some High Protein-containing Foods

Protein source	% casein* (rat)	Regression coefficient N absorbed to N retained** (children)
Whole egg	101	98
Whole milk	89	95
CSM	78	54
Superamine	93	67
TRL	83	76
IRL	85	76
Incaparina No. 9***	67	64
Incaparina No. 14	78	82
Incaparina No. 15	76	62

*Casein PER = 100
**Percentage of reference protein
***Without lysine
(From Viteri, F. E. and Bressani, R., *Bull. WHO*, in press. With permission.)

TABLE 3

Ingredient Composition of Some High Protein-containing Foods

High protein food	Incaparina No. 9	Incaparina No 14	Incaparina No 15	Soyacyt	Bal-Ahar Form A	Bal-Ahar Form E
Country	Guatemala and C A	Colombia	Colombia	Mexico	India	India
Soybean flour		X	X	X[1]		
Cottonseed flour	X		X			
Sunflower flour						
Peanut flour					X	X
Sesame flour						
Torula yeast	X					
Chickpea					X	
Lentil flour						
Skim milk				X		X
Fish Protein Concentrate						
Maize	X	X	X			
Wheat					X[2]	X[2]
Rice		X				
Teff						
Lysine	X					
Methionine						
Vitamins	X	X	X		X	X
Minerals	X	X	X	X	X	X
Flavoring agents				X		
Antioxidants						
Protein, %	25	25	25	21	24	21
PER	2.5	2 2	2 0	-	2 0	2 4
Main use	gruel	gruel	gruel	drink	gruel	gruel

High protein food	MPF Form A	Faffa SM 8'B	Pro Nutro	Superamine	Duryea	Leche Alim
Country	India	Ethiopia	S Africa	Algeria	Colombia	Chile
Soybean flour			X		X	
Cottonseed flour						
Sunflower flour						X
Peanut flour	X	X				
Sesame flour						
Torula yeast						
Chickpea flour	X	X		X		
Lentil flour				X		
Skimmilk		X	X	X	X	X
Fish Protein Concentrate						X
Maize			X		X[5]	
Wheat			X[4]	X		X[6]
Rice						
Teff		X				
Lysine						
Methionine						
Vitamins	X			X	X	
Minerals	X			X	X	
Flavoring agents		X[3]		X		
Antioxidants						
Protein, %	42	13-14	22	21	28	27
PER	1 80	3 00	71*	2 40	2 40	
Main use	protein supplement		cereal & soup mix		weaning food	drink

TABLE 3 (continued)

High protein food	CSM	VPM	Vitalia	Laubina 104	TRL	IRL
Country	world-wide	Middle East count.	Colombia	Lebanon		
Soybean flour	X	X	X		X	
Cottonseed flour						
Sunflower flour						
Peanut flour						
Sesame flour		X				
Torula yeast						
Chickpea flour		X		X	X	X
Lentil flour						X^{9}
Skimmilk	X			X	X	X
Fish Protein Concentrate						
Maize	X		X			
Wheat			X^{6}	X	X	X
Rice			X			
Teff						
Lysine						
Methionine						
Vitamins	X			X	X	X
Minerals	X			X	X	X
Flavoring agents				X		
Antioxidants						
Protein, %	19	37.8	17.8	16.8	21	18
PER	2.40	-	2.69	2.28	2.30	1.98
Main use	gruel	gruel	macaroni	weaning	weaning	weaning

X^{1} = Full fat soybean flour
X^{2} = Whole wheat flour
X^{3} = Sugar and salt.
X^{4} = Wheat germ
X^{5} = Opaque-2 maize
X^{6} = Toasted wheat flour
X^{7} = Low fat soybean flour
X^{8} = Wheat semolina
X^{9} = Split pea flour
* = NPU (Net Protein Utilization)
X = Either one

and minerals more deficient in the human dietary of the country or area where the food is being distributed and hopefully consumed. It should also be indicated that there are various formulations for the same product in many cases.

All these foods have many characteristics in common. They are of high nutritive value and were developed to meet specific nutrient needs and acceptability requirements since they resemble traditional accepted products with respect to taste, texture, and flavor. Furthermore, they are easy to handle and prepare for consumption and have a relatively long shelf life. At the beginning, in the formulation of high protein foods, the ingredients used in the formula were in a sense not well defined, even though the components met quality specifications.[47,50-52]

As research advanced, the ingredients utilized became more technologically sophisticated, permitting diversification of the form and uses of these high protein-containing foods. As animal proteins become less available and thus more expensive, in future years these high protein foods may be expected to take their place; this is already possible now, since plant protein is being processed into more acceptable forms than in previous years.

Fortification

In the last few years, attempts have been made to standardize the terminology used in the improvement of the nutritive value of foods. This has been a rather difficult task because of the interrelationship between the nutrients added and the food to be supplemented. Indeed, it is rather arbitrary to establish a definite boundary among the different approaches used to improve the nutritional quality of foods, as will be seen in the following discussion. However, efforts will be made, first, to define the scope covered by the different procedures and, second, to try to illustrate as much as possible, practical examples of each one of them.

Fortification will be defined here as the addition of specific nutrients in higher amounts than that found in natural foods. Fortification technology can be achieved by the addition of synthetic amino acids, protein concentrates, protein concentrates plus synthetic amino acids, and other specific nutrients (vitamins and minerals).

Synthetic Amino Acids

The production of some amino acids at a reasonable commercial cost has permitted their supplementary use to improve the protein quality of some important foods. Cereal protein, for example, can now be significantly improved by the addition of synthetic amino acids. Table 4 summarizes the results of several experiments carried out on the supplementation of lime-treated corn with its limiting amino acids.[53] Protein quality is more than doubled by the addition of lysine and tryptophan, thus changing a poorly utilized protein into a relatively high quality protein food. These results show the beneficial effect of the limiting amino acids, as well as the best ratio found for lysine and tryptophan as far as protein quality is concerned.

Similar improvement can be obtained with rice, wheat, oats, soybean, and other foods.[35]

Protein Concentrates

It is obvious that the addition of synthetic amino acids improves protein quality but does not change protein quantity. The second alternative, namely, the use of protein concentrates, has the advantage of not only supplying the deficient amino acids, but also of providing an increment in the total protein content. This is very important when the supplemented food is of a low protein concentration, as is the case of cereals. Table 5

TABLE 4

Supplementation of Lime-treated Corn with Amino Acids

Amino acids*	Average weight gain**	Protein efficiency ratio
Masa***	32	1.21
Masa + 0.31% lysine	41	1.51
Masa + 0.10% tryptophan	22	1.15
Masa + 0.31% lysine + 0.05% tryptophan	100	2.66
Masa + 0.31% lysine + 0.05% tryptophan + 0.20% threonine + 0.20% isoleucine + 0.15% methionine	112	2.69

*L-lysine HCl, DL-tryptophan, DL-methionine, DL-threonine, DL-isoleucine
**Average initial weight for all experiments: 48 to 52 g
***Masa dough prepared from lime-treated cooked corn
(From Bressani, R. et al., *Arch. Latinoamer. Nutr.*, 18, 126, 1968. With permission.)

TABLE 5

Optimum Levels of Protein Concentrates to Supplement Lime-treated Corn and Rice

Protein concentrate	Corn: Optimum level % in diet	Corn: Protein efficiency ratio	Rice: Optimum level % in diet	Rice: Protein efficiency ratio
–	–	1.00	–	1.73
Egg protein	3.0	2.24	–	–
Casein	4.0	2.21	6.0	3.22
Meat flour	4.0	2.34	–	–
Fish flour	2.5	2.44	6.0	2.70
Soya protein	5.0	2.30	–	–
Soya flour	8.0	2.25	8.0	2.88
Cottonseed flour	8.0	1.83	12.0	2.32
Torula yeast	2.5	1.97	8.0	3.29
Skim milk	–	–	12.0	3.16

(From Elías, L. G. et al., *Arch. Latinoamer. Nutr.*, 18, 35, 1968. With permission.)

shows an example of this fortification procedure, as applied to corn and rice proteins. The results show the optimum levels of each supplement necessary to obtain a maximum biological response when added to corn protein. It was found that the amounts of lysine and tryptophan in the supplements used correlated highly with the improvement in protein quality as measured by protein efficiency ratio (Figure 1).[32] Similar results are obtained with the supplementation of rice with protein concentrates.[54] In this case, a high correlation coefficient was obtained between PER (Protein Efficiency Ratio) and the amounts of lysine and threonine present in the supplements, since these two amino acids are the most limiting in rice protein. It should be noted that in some cases, the addition of protein supplements is used to provide the limiting amino acids plus additional protein, as in the case of cereal grains; in other cases, they are added only to provide the limiting amino acids, as for example, the addition of protein concentrates rich in lysine to cottonseed flour,[21] which is deficient in this amino acid and by-products from the wheat milling industry.[55]

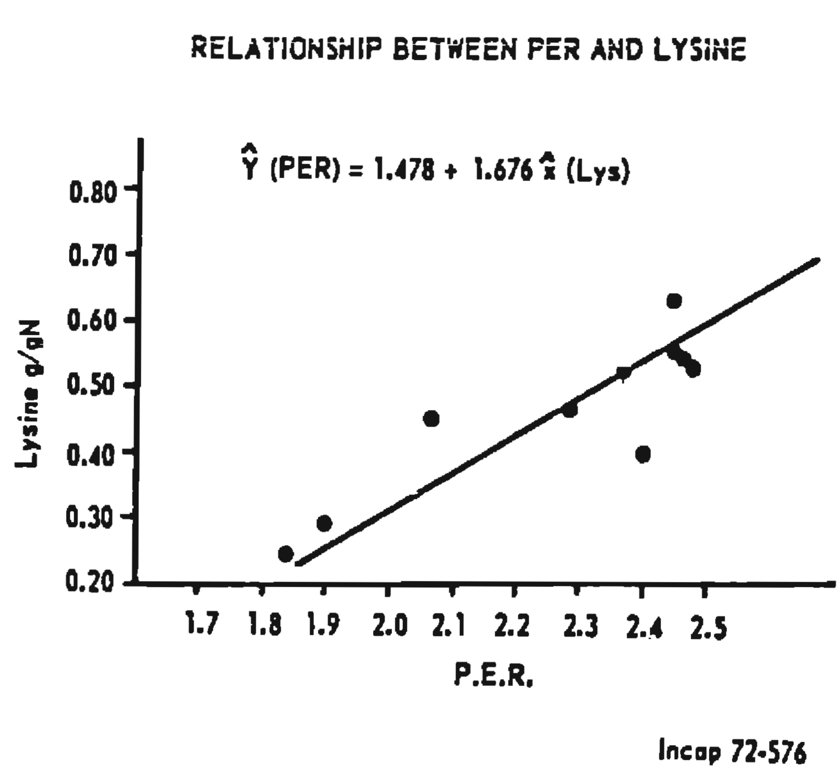

FIGURE 1.

Protein Concentrates Plus Amino Acids

Another procedure is the combination of the two alternatives previously mentioned, that is, the addition of a protein concentrate plus the complementary aggregate of the amino acid that the supplement does not provide in optimum amounts.

The results shown in Table 6 indicate that the addition of 0.1% lysine to corn supplemented with 8% soya flour increased utilizable protein as compared to the diet supplemented with amino acids or with 8% soya flour (Table 5). As a matter of fact, this additional improvement is a question of economy, since this increment could also be accomplished with a lower efficiency of utilization by raising the level of the protein concentrate used as the supplement.

TABLE 6

Effect of Various Supplements on the Nutritive Value of Corn[40]

Protein	Protein %	PER	Relative nutritive value** %	Utilizable protein %
Corn*	7.9	1.26	33.7	2.66
Corn* + 0.3% Lys + 0.1% Tryp	8.0	2.78	74.5	5.96
Corn* + Soya flour + 0.1% Lys	9.7	2.43	65.1	6.31
Casein	9.8	2.80	75.0	7.35

*Lime-treated corn
**Relative nutritive value to casein

Other Specific Nutrients (Vitamins and Minerals)

As has been mentioned elsewhere in this chapter, the lack of protein both in quality and in quantity is the most important problem in the developing areas of the world from the nutritional point of view. It must also be emphasized, however, that a well-balanced protein requires the presence of other micronutrients to perform its function with a higher efficiency of utilization. The need for these additional nutrients is not really appreciated in practice, in part, due to the obvious interrelationships among them or because the methodology used in protein evaluation must fulfill all those requirements to be valid. Since some of those other nutrients are also limiting in the daily diets of poor socioeconomic populations, it is important to take this aspect into consideration. This point is clearly shown in the results obtained by Bressani and Marenco[32] when supplementing tortilla flour with amino acids and vitamins. As illustrated in Table 7, the addition of the most limiting amino acids improved the quality of corn protein; however, a further significative increase was obtained when thiamin, riboflavin, and niacin were added to the amino acid-supplemented diet. Similar results were observed with vitamin A. As in the previous case, vitamin A has been reported as deficient in the diets of many parts of the world.

These concepts are even more important when the staple food is the one to be fortified, as for example, in the case of corn or rice which provides the main source of protein for large segments of populations. This aspect is illustrated in Table 8, which shows the effect of the individual addition of groups of nutrients on the quality of a corn-bean diet;[40] these two foodstuffs are the basic components of the daily diets of many low socioeconomic groups in Latin America.

From these data, it is clear that the addition of minerals as a group was the most important followed by the vitamins; of significance, however, was the fact that the addition of lysine and tryptophan in the absence of those nutrients showed no improvement as compared to the unfortified basal diet. Other important considerations are implicated in these results, as can be observed in Figure 2, which shows the weight gain of rats fed some of these diets for eight weeks; the tendency is that the differences in protein utilization become greater as the animals are kept under the same experimental conditions for a longer period of time. These results can be explained on the basis that, for its better utilization, a higher protein quality requires higher amounts of other nutrients which are normally limiting in these diets; these become even more limiting when the main protein deficiencies are corrected. Although these are experimental data obtained in well-controlled laboratory conditions, one is tempted to think that for people subsisting on poor protein quality diets, it is "fortunate," from the nutrition point of view, also to have inadequate amounts of other essential nutrients.

Other Important Aspects

If fortification technology is going to have an

TABLE 7

Effect of Adding Lysine, Tryptophan, and Vitamins on the Nutritive Value of Tortilla Flour*[32]

Nutrient added**, ***	Initial weight g	Weight gain g/28 days	Protein efficiency ratio
None	52	38	0 91
Riboflavin + Thiamine + Niacin	51	54	1 05
Lysine + Tryptophan	46	70	1 62
Lys + Try + B_1 + B_2 + Niacin	46	173	2 41
None	52	78****	
Lysine + Tryptophan	53	124****	
Vitamin A	53	80****	
Lysine + Tryptophan + Vitamin A	52	149****	

*Amount of tortilla flour. 90%
**Amount of riboflavin, thiamine and niacin added 3 mg/100 g
***Amount of L-lysine HCl 0 41%, DL-tryptophan 0 10%
****Weight gain in g/70 days

TABLE 8

Effect of the Individual Addition of Groups of Nutrients on the Quality of Corn-bean Diet*[40]

Treatment of corn-bean diet	Average food-intake g/28 days	Average weight gain* g/28 days	PER
None	271 ± 8.8*****	26 ± 2 3*****	1 09 ± 0 07*****
+ Vitamins**	367 ± 18 7	49 ± 4 0	1 52 ± 0 06
+ Minerals***	388 ± 15 8	65 ± 4 3	1 91 ± 0 06
+ Lys + Try****	266 ± 14 4	26 ± 2 5	1 10 ± 0 08
+ Vit + Min	425 ± 10 5	70 ± 2 1	1 90 ± 0.04
+ Vit + Min + Lys + Try	484 ± 14 7	107 ± 4 9	2.55 ± 0 06

*72 4% corn + 8 10% bean
*Average initial weight 44 g
**Recommended levels for lab rats (B-complex and A, D, E, K)
***Recommended levels for lab rats
****0 25% L-lys HCl and 0 025% DL-try
*****Standard error

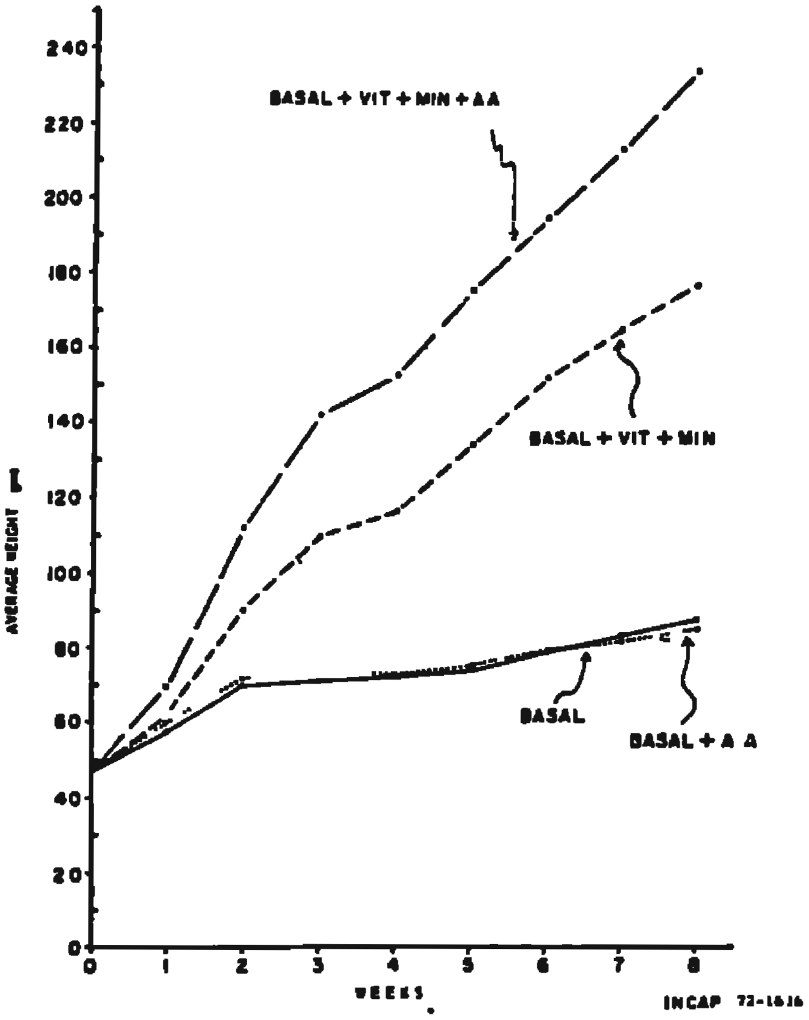

FIGURE 2 Effect of addition of lysine and Tryptophan to a corn-bean diet in the presence and absence of vitamins and minerals

impact in providing nutritious foods, the following additional points must be taken into consideration.

The criteria in selecting the nutrients to be added, as well as their level, must be related not only to the food itself, but also to its contribution to the whole diet usually consumed The results in Table 9 illustrate this point, the daily diets of a large group of people in Latin American countries are based on corn and beans which are of low protein content and quality due to the fact that they contain higher amounts of corn as compared to beans If fortification is applied to bean protein by the addition of methionine, no improvement in the nutritional quality is observed. However, the use of a high protein bean with a higher lysine and tryptophan content almost doubles the protein utilization of the basal diet, since these two amino acids are the most limiting in this diet.

The nutrient(s) added should not change the physical and organoleptic properties of the supplemented food The yellow color of cottonseed flour or the particular taste of *torula* yeast has probably been the disadvantage of the use of those protein concentrates as supplements On the other hand, soybean flour has been successfully accepted by its favorable characteristics For example, tortilla

TABLE 9

Effect of Fortified Beans on the Performance of Rats and Quality of Corn-bean Diets

Dietary treatment	Average weight gain, g/28 days	PER
72 4% maize + 8 1% beans	69	2.11
72 4% maize + 8 1% beans + 0 30% L-Lys HCl + 0 10% DL-Try	103	2.64
72 4% maize + 8 1 % beans + 0 30% DL-Met	66	1 93
72 4% maize + 8 1% beans + 0 30% L-Lys HCl + 0 10% DL-Try + 0 30% DL-Met	108	2 69
	Average weight gain, g/28 days	Utilizable protein %
87% Maize + 13% Beans (23% Prot)	48	4 54
87% Maize + 13% Beans (35% Prot)	72	5 87

flour does not change its common color by the addition of soybean flour, wheatshorts, or glandless cottonseed flour; however, the addition of edible cottonseed flour from common cottonseed gives a light-yellow color to the supplemented tortilla. Other acceptability trials must also be carried out to meet the requirements set by the consumers.

The added nutrient(s) must be stable to the normal processing conditions used in the preparation of the food to be supplemented. In general, foodstuffs are submitted to heat treatment before they are consumed to improve their texture, palatability, and sometimes, digestibility. Furthermore, it is important to carry out stability studies to assure that the added nutrients are not destroyed or inactivated during processing and storage.

Large-scale processing techniques for the preparation of the supplemented food are also of the utmost importance because in the developing countries foods are generally homemade, constituting a problem for the successful application of fortification technology. Adequate methods for the addition of the nutrients to the food at an industrial level must be studied. Since in these areas of the world food industries are generally located in urban centers, it is also important to recommend adequate methods of transportation to the rural areas, where undernutrition is more prevalent. Industrial processing also insures a more homogeneous product available all the time and in different convenient food forms. Although there are many problems to be solved on the implementation of the fortification technology, it represents a valuable way to improve the shortage of nutritious foods in the world.

Restoration

Restoration can be defined as the addition of a nutrient to a particular food to restore its original chemical composition. In a broader sense, restoration can also mean the total or partial replacement of a processed food by another food. In both cases, the purpose is to recover and/or improve the nutritive value or the physical and organoleptic properties altered during processing. Sometimes restoration technology aims at economic aspect, as for example, the replacement of wheat flour by a flour prepared from cassava or sweet potatoes without paying attention to the nutritive value of the product. However, in this section, emphasis will be placed only on the nutritive aspects of restoration; examples of this technology can be found in the literature. Tortillas, a staple foodstuff in some Latin American countries, can be improved by using this technique. In this case, part of the tortilla flour was replaced by wheat shorts, a by-product of the wheat milling industry. The amount replaced ranged from 0 to 30% and the results obtained are shown in Table 10. In this case, the significant improvement obtained in the nutritive value of tortilla is due to the amounts of lysine and tryptophan present in the wheat shorts, as well to an increment in protein content of the mixture.[23] Organoleptic tests were carried out in the tortillas made from this mixture; the results indicated that the appearance and texture were

TABLE 10

Effect of Replacing Lime-treated Corn Flour by Various Levels of Wheat Short on Nutritive Value

Amount of lime-treated corn-flour, %	Amount of wheat short flour, %	Protein in diet, %	Average weight gain, g	PER	Relative Nut. value to casein %	Utilizable protein, %
70	–	7.0	18	1.07	29.7	2.08
70	10	9.0	36	1.42	39.4	3.55
70	20	11.0	72	1.88	52.2	5.74
60	30	12.0	93	2.06	57.2	6.86
90	–	9.0	31	1.10	30.5	2.74
Casein	–	10.0	120	2.70	–	–

Average initial weight: 47g
Biological value of casein: 75%

(From Bressani, R., *Proceedings Western Hemisphere Nutrition Congress III*, 1972, 374. With permission.)

not affected by such a replacement, although a characteristic flavor of bread was detected. Consumer preference tests, however, were positive for the supplemented tortilla.

Similar reports have been made by Ranhotra[56] using a wheat protein concentrate (WPC) to partially replace wheat flour for the preparation of bread. This author studied the nutritive value as well as the rheological and baking characteristics of the different mixtures of wheat flour and WPC. He found that the improvements obtained in the protein quality and quantity were directly proportional to the levels of WPC added. He explained these results on the basis of the lysine content of the WPC. As far as baking characteristics were concerned, he found that the loaf volume was most affected by the addition of this supplement.

Encouraging improvement has also been obtained with this product in the preparation of chapatties,[57] a type of bread consumed in India and with other wheat-based foods.[58] Breads made with cassava flour and peanut or soybean flour have a higher nutritive value compared to those made with wheat flour only, as has been reported by Kim and De Ruiter.[59] Cassava flour has also been used to replace wheat flour in the preparation of some breads;[60] to improve the protein quantity and quality of this mixture, 6% of soybean flour is added. In these last two examples, the economic aspect is also favored, since cassava flour is less expensive and more available than wheat flour.

This approach can also be used to extend the availability of some higher nutritious foods; for example, Dutra de Oliveira and Da Silva[61] have suggested the partial replacement of common maize by Opaque-2 maize to improve the protein quality of the former.

Enrichment

Enrichment technology is concerned with the addition of nutrient(s) to a specific food to utilize it as a carrier for this nutrient(s). In general, the nutrient(s) added is not a component normally expected in the food and as a consequence, its supplementary value is improved; however, in some cases, the nutritive value of the particular food is enhanced. As the definition implies, the enrichment procedure must be employed only under well-controlled conditions to avoid undesirable effects; this means that both the vehicle and nutrients added should be well characterized in terms of the quality and quantity they will provide to the diet of the population group for which they are intended. Perhaps the most important consideration in relation to this procedure is the selection of the appropriate vehicle for the nutrient(s), that is, their suitability to fulfill the nutritional function in terms of stability, processing conditions, and consumption, both in frequency and amount, and in relation to the flavor and appearance of the product.

Obviously, in the case of the nutrient added, minimum levels of tolerance must be determined, as well as its interrelationship with the other nutrients present in the diets, this last requirement perhaps being the most difficult to foresee in practice.

Due to the relatively complicated mechanism, examples of enrichment technology as related to protein nutrition are scarce, as compared to restoration and fortification technology. The use of cassava flour as a carrier for the amino acid methionine has been proposed by Dutra de Oliveira and Menezes Salata for the northern and northeastern parts of Brazil.[62] In that country, cassava flour is eaten with common beans (*Phaseolus vulgaris*); the nutritive value of this mixture is of low protein quality because common beans, although relatively high in protein content, are limiting in methionine.[1]

Table 11 shows the results of the experiment carried out by these authors to illustrate this point. As expected, in all three combinations used, the addition of methionine to the cassava flour improved the nutritive value of the diets; the difference in weight gain observed among the combinations is due to the higher amounts of protein provided by common beans.

Although these results are clear and the principle is sound, other questions should be answered before it can be useful in practice. For example, it is essential to know the amount of beans usually consumed in the diet, as well as if other foods are also consumed with cassava flour. These are important points in relation to the level of methionine that should be added and the degree of improvement expected.

Table 12 shows the results obtained when the ratio of cassava to beans in the diet is higher[63] than that used in the experiment of Dutra de Oliveira and Menezes Salata.[62] As can be seen, the supplementary effect of methionine is ob-

TABLE 11

Protein Quality of Manioc Flour with and without Methionine Addition Mixed with Various Levels of Beans*

Dietary treatment	Protein, % in diet	Average weight gain, g	PER
65% manioc flour + 35% bean flour	8.04	7.7	0.78
65% manioc flour + 0.6% methionine + 35% bean flour	8.85	68.2	2.70
55% manioc flour + 45% bean flour	9.97	14.2	0.96
55% manioc flour + 0.6% methionine + 45% bean flour	10.09	66.8	2.68
45% manioc flour + 55% bean flour	12.17	31.7	1.28
45% manioc flour + 0.6% methionine + 55% bean flour	12.23	71.0	2.27

(From Dutra de Oliveira, J. E. and Menezes Salata, E.B.Z., *Nutr. Pre. Int.*, 3, 291, 1971. With permission.)

TABLE 12

Effect of Adding Methionine on the Nutritive Value of Various Cassava-beans[63] Mixtures

Dietary treatment	% Protein in diet	Weight changes g/28 days	PER	Cassava/bean ratio
Cassava (100)	1.9	−16.0	–	–
Cassava (87) bean (13)	4.3	−10.0	–	6.7
Cassava (87) bean (13) + methionine*	4.1	−7.0	–	6.7
Cassava (74) bean (26)	6.4	−6.4	–	2.8
Cassava (74) bean (26) + methionine*	6.7	+29.0	1.78	2.8
Cassava (61) bean (39) ·	8.8	+11.0	0.66	1.56
Cassava (61) bean (39) + methionine*	9.0	+67.0	2.42	1.56

*Figures in parenthesis refer to amounts, in grams, in the diets
**Amount added: 0.03 g of DL-Methionine per gram of bean protein

served only when the ratio of cassava to beans is similar to that reported in their study [62]

Other examples of enrichment technology include the addition of vitamins and minerals, as for instance, the addition of vitamin D in milk to fight rickets in infants, the use of salt as carrier of iodine or iron to help in the prevention of goiter or anemia, and the addition of vitamin A in margarine and in sugar.[64]

Although these last examples are not directly related to protein nutrition, they are contributing to making a variety of foods convenient sources of essential nutrient, thus solving many nutritional deficiencies.

The addition of nutrients to foods that are not natural sources for such nutrients is a matter which has different implications for populations with a relatively high state of nutrition, such as those in developed countries in contrast to populations in developing countries In these, there are groups of people consuming diets that are nutritionally as good as those consumed in developed countries, as well as the majority of people who consume diets of poor nutritive quality, deficient in more than one nutrient

In such a common situation, consideration must be given to various factors If the diet is deficient in three or four nutrients, enrichment with only one may cause greater undesirable effects than those occurring without it. This is even more meaningful if the nutrient added is related to one present in the diet On the other hand, if the nutrient added is related metabolically to one not added at the same time or absent in the diet, the effect from it can be less than expected or none at all. The level of the nutrient to be added is also significant. If it is high, it may cause problems for those already ingesting adequate amounts of it

The choice of the carrier is also of importance in the case of enrichment programs for developing countries. In the opinion of the authors, it is not advisable to choose a universal carrier, such as salt or sugar, because it is consumed by the entire population of such a country Such approaches have been proposed for vitamin A in sugar[64] and iron in salt[65] The case of vitamin A in sugar probably better illustrates the implications of such an approach. While sugar is consumed by all groups of people, in developing countries sugar consumption follows a gradient based on dietary habits, economic status, and diversity of foods reaching the dining room table Therefore, those people with nutrient deficiencies may not ingest enough of the nutrient because they consume less of the carrier. Those without nutrient deficiencies will ingest more of the nutrient because they consume more of the carrier from various sources, including vitamin pills

It would appear that for developing countries, enrichment should be done on a carrier which provides other nutrients as well and is consumed with a greater frequency by the population which is deficient in the nutrient in question. Although this approach has its limitations, it has more advantages and is less risky for the overall population

Replacement

From time to time during the last few years, it has been indicated that world milk supplies are constantly decreasing with little hope of equaling the amounts of 10 years ago Vegetable protein sources have become very useful in increasing the availability of dried milk supplies, particularly if the vegetable protein isolate has the functional properties and physical and organoleptic characteristics required to extend milk supplies

Over the last few years, a product known as toned milk became popular in India[66] This product contained 50% reconstituted skim milk powder and 50% fresh whole milk standardized to 3% fat. The milk powder was imported, making it relatively expensive and possibly incapable of continuously producing the tone milk A substitute was developed containing 50% animal milk and 50% vegetable milk, prepared from peanut protein isolate and dextro maltose Similar types of preparations have been described by Bressani,[45] however, the vegetable product used consisted of very fine cottonseed or soybean flour and carbohydrate sources. These products have a high protein quality, but lack the physical characteristics of toned milk, as indicated above. Similar products containing 25% milk powder and peanut and cereal flours supplemented with methionine have also been described[67] These, however, could be reconstituted as fluid milk and had a protein efficiency ratio of 2.70.

The same approach for other food preparations has also been reported. For example, skim milk added to soybean milk has been made into cheese by lactic fermentation, yielding a product with a good flavor and with a possible high protein quality, depending on the amount of skim milk used.[68,69]

Along the same lines, a soy cheese whey protein preparation has been described The mixture used consisted of three parts of soy protein to one part whey protein. The product was obtained by heating at 98°C at a pH of 4 7, was used with corn grits, giving a food product with a protein quality superior to that of soy protein-corn or casein-corn mixtures[70]

PROCESSING

Oil-containing seeds have been extremely useful in the preparation of a variety of highly nutritious foods, the most common of which is the oil-free flour as has already been mentioned They have also served as raw materials for the preparation of protein isolates, however, special processing techniques have made it possible to produce high protein foods from the native kernel For example, Lawhon, Cater, and Mattil[71,72] have described a process for the preparation of a high-protein nut-like food from glandless cottonseed kernels The food product known as Tamunuts could be produced by oven roasting, toast-steam, pressure steaming-oven roast, or deep-fat frying Protein content of cottonseed kernels produced by any technique varied from 33 to 37% with at least 79 to 94% of it in insoluble form Oil content varied from 38 to 43% The authors indicated that consumer response to the food items from Tamunuts was highly favorable in acceptance tests By applying high pressures at various temperatures, times, and moisture levels, Pominski, Pearce, and Spadaro[73] prepared partially defatted peanuts High protein full-fat products have been produced from soybeans by extrusion cooking.[74] Flours of high protein quality, flavor, and good stability were prepared by dehulling and preheating the extracted soybean meats to inactivate lipoxidase, premixing with water to add moisture, extruding, cooling, drying, and grinding The product contained about 41% protein with 22.5% fat and its protein efficiency ratio was 1 98, adjusted to a 2 5 value for casein.

Soybean milk has been prepared for a long time in the Orient by soaking beans in water for several hours, followed by grinding with water, filtration, and cooking Although this process method is relatively simple, soymilks obtained from such a process usually have a bland or undesirable aroma.

Wilkens, Mattick, and Hand[75] and Hand et al [76] described a process using a high temperature, rapid hydration grinding process that gave a nearly bland soymilk The process consists of grinding unsoaked, dehulled soybeans with water at temperatures between 80 and 100°C and maintaining the temperature for 10 min to completely inactivate the lipoxidase enzyme system, the primary factor in off-flavor production.

Fermentation has been very useful in preparing better quality foods in the Orient with the soybean, alone or in mixtures with rice and other foods [1]

TEXTURED VEGETABLE PROTEIN FOODS

The high cost of meat, resulting mainly from the relatively low efficiency with which the animal is able to transform vegetable protein into muscle has been one of the factors which stimulated the development of what is known today as "textured vegetable protein foods"[77,78] These foods had their origin from the advances made in protein isolation techniques together with synthetic fiber technology, which permitted the development of protein food with the physical, organoleptic, and nutritional characteristics associated with meat The textured vegetable protein foods are made from oilseed or cereal products, and processed in the form of fibers, cubes, chunks, chips, or granules The isolated protein converted into filaments provides textured products which are blended with fat, flavor, coloring stabilizers, and supplemental nutrients All of these components are then bound together with a heat-coagulable protein

These foods can also be made by thermoplastic extrusion, in which a mixture of soybean flour, flavoring and coloring components, and water is subjected to heat and pressure for specific periods of time After cooking, the mass is extruded into atmospheric pressure which causes expansion. By the use of the appropriate size and shape of dyes, different forms can be made.

Since they are man-made, these textured foods may be converted into highly nutritious foods. In most cases, the protein base has been derived from soybean, which is low in sulfur-containing amino acids, but the addition of other components can overcome such a deficiency For example, egg albumin is the most widely used binding agent and it is one of the highest quality proteins The nutritive value of this textured food can be high and some results are shown in Table 13 In this case, the textured food was a simulated ground beef.[79] The performance of the animal species used to evaluate its protein quality is quite good, comparable to natural beef or casein. Likewise, the results in children show it to be a food of a relatively high protein value.

As indicated above, the nutritive value can be improved even further if there is any need to do so These foods offer great stability, uniformity, organoleptic variety, nutritional control, and, eventually, economy.

TABLE 13

Protein Quality of Soybean Textured Food in Rats, Dogs, and Children

Protein food	Protein in diet, %	Average weight gain, g	PER
	Protein quality in rats		
Soybean protein textured food	11.6	125	2.69
Casein	11.7	116	2.66
Dehydrated beef	12.2	123	2.66

Nitrogen balance in dogs

	Intake	Fecal	Urine	Absorbed	Retained	Retention % intake
	Nitrogen					
	mg/kg/day					
Soybean textured food	261	55	138	206	68	26.0
Dehydrated beef	292	69	149	223	74	25.3

Nitrogen balance in children

	Intake	Fecal	Urine	Absorbed	Retained	Retention % intake
	Nitrogen					
	mg/kg/day					
Soybean textured food	312	46	183	266	82	26.6
Milk	342	52	210	290	80	23.4

(From Bressani, R., *J. Nutr.*, 92, 357, 1967. With permission.)

THE ROLE OF GENETICS ON THE DEVELOPMENT OF HIGHLY NUTRITIOUS PRODUCTS

For some time, food chemists and some plant breeders have known that protein concentration and even amino acid content, as well as other nutrients in cereals, legumes, and other products of vegetable origin, vary widely, depending on genetic and environmental factors. This variation was, however, not fully appreciated until 1964, when Mertz, Bates, and Nelson[80] reported that a strain of maize homozygous for the recessive mutant gene, Opaque-2, had a significantly higher lysine and tryptophan content than normal maize. This research has produced a major breakthrough in plant genetics and it constitutes what could be a very formidable approach to the development of highly nutritious food products, particularly in those more often consumed by the great majority of the world population, that is, cereal grains and legume foods. This approach to better nutritive food products could be named *genetic fortification.*

In the particular case of maize indicated above, the Opaque-2 gene caused an increase in the essential amino acids, lysine and tryptophan, by reducing the concentration of alcohol soluble proteins in maize and increasing the concentration of the sodium hydroxide protein fraction, richer in the two amino acids. Although little appreciated, the Opaque-2 gene also caused a reduction in the amino acid leucine which, being in high concentration in normal maize protein, may contribute to the low protein quality of normal maize and could also be related to the development of pellagra, or niacin deficiency.[81,82] In terms of nutritional value, Opaque-2 maize has a biological value in human adults and children of 92 and 72%, respectively, as compared to egg protein with a value of 96% for adults, and milk with 80% for children.[38,83] The role of genetics in developing better nutritive quality foods has also been demonstrated with other food crops or sources of protein.

Through genetic manipulation, it was possible to develop cottonseed varieties free of the pigment gossypol in 1953. These varieties were called glandless to indicate that they did not contain the glands which hold the gossypol pigments. It has been known for some time that gossypol is a toxic substance for monogastric animals[84] and the presence of this substance in cottonseed has limited its use in nutrition. Furthermore, upon processing to remove the oil from the seed, gossypol pigments are responsible to a large degree in the characteristic color of cottonseed flour. Upon processing, glandless cottonseed yields a flour as light in color as soybean flour. The nutritive value of the protein from glandless cottonseed is superior to that from common cottonseed. Similar results are also being reported for other protein sources. For example, some varieties of rapeseed low in erucic acid as well as a variety of the same seed low in glucosinolate have been found. Genetic improvement is not limited to protein quality or freedom from toxic substances. Research has also indicated that through genetic selection, the quality of vegetable oils can be changed to contain desired concentrations of oleic and linoleic acids in safflower, soybean, and other oils from oil-containing seeds.[85,86] Vitamin content can also be modified by genetic means.

SIGNIFICANCE AND ROLE OF HIGHLY NUTRITIOUS PRODUCTS

The idea of upgrading the nutritional quality of the foods consumed by man is really not one developed within the last 15 or 20 years, but one which evolved since early in this century. The need for such upgrading was really not world-wide, but rather for specific population groups who suffered from vitamin deficiency caused by consumption of foods that processing had degraded from the nutritional point of view, although upgraded in terms of acceptability. The addition of the nutrients eliminated during processing improved their nutritional quality and eliminated the deficiencies found in the human population consuming them.[87]

Upgrading the nutritional quality of foods today and in future years is more pressing because of factors already discussed and well accepted; the objective is to achieve the highest utilization efficiency of the food consumed. This concept of efficiency of utilization is not well understood or applied, but it may be as important to the world as increasing food production.

One of the aspects in agricultural research which receives particular attention is that of increasing yield of a food crop per unit area, rather than increasing yield by expanding the total area of cultivation. In this way, production is more efficient in terms of utilizing to the maximum possible the nutrients from the soil, the available water, and carbon dioxide and the solar energy. Similarly, in animal production, the objective is to produce a maximum of a product with the minimum feed at the lowest cost, emphasizing again the efficiency of production. Human populations are of course not plants or animals and their nutrition is really not for the same purpose; however, because of increasing populations, dietary habits, food availability and, possibly, other factors, it is becoming increasingly necessary for foods to be utilized with the greatest efficiency. This increased efficiency of nutrient utilization is the significance of improving the quality of food supplies and of developing highly nutritious foods.

Increased food production has taken place in the world in previous years by improved varieties and hybrids, control of soil fertility and of insects, and by various other agronomic developments. The more recent of the impacts of agricultural research is the *green revolution*, which was achieved by the use of improved varieties responding to the application of fertilizers and water. The emphasis has been on the cereal grains; it is hoped that soon the same result will be accomplished also with legume foods. The consumption of both cereal and legume grains has probably kept many populations in a certain degree of nutritional health, providing them protein diets of higher quality than those from cereals alone. But increased production of legume grains will provide even better protein nutrition when consumed with cereal grains. This may be also considered as the development of highly nutritious foods.

The new technology can be of significant help to the expanded production derived from the *green revolution*. This will increase as greater numbers of people move from rural to urban areas, depending more and more upon processed foods. Through the *green revolution* it is possible to produce greater amounts of foods, and it will be possible to develop better nutritive quality foods through food technology. Examples of this have already been given in previous sections. From the standpoint of protein nutrition, animal products are and have been the main source of protein for developed populations, and even for primitive civilization when population and economic pressures were not as great as they are today and will be in future years. The role, therefore, of the highly nutritious foods, whether from the efforts of agronomy or from food technology, would be to replace the animal food products that are inefficiently produced in most cases, particularly if they are produced from foods which may be or are also consumed by humans.

REFERENCES

1. Bressani, R. and Elias, L. G., Processed vegetable protein mixtures for human consumption in developing countries, *Adv. Food Res.*, 16, 1, 1968.
2. Bressani, R. and Elías, L. G., Legume foods, in *New Protein Foods*, Vol. I, Altschul, A. M., Ed., Academic Press, to be published.
3. Bressani, R., Elías, L. G., and Navarrete, D. A., Nutritive value of Central American beans. IV. The essential amino acid content of samples of black beans, red beans, rice beans and cowpeas of Guatemala, *J. Food Sci.*, 26, 525, 1961.
4. Elías, L. G., Colindres, R., and Bressani, R., The nutritive value of eight varieties of cowpeas *(Vigna sinensis)*, *J. Food Sci.*, 29, 118, 1964.
5. Patwardhan, U. N., Pulses and beans in human nutrition, *Am. J. Clin. Nutr.*, 11, 12, 1962.
6. Jaffé, W. G., Protein digestibility and trypsin inhibitors activity of legume seeds, *Proc. Soc. Exp. Biol. Med.*, 75, 219, 1950.
7. Bressani, R., Elias, L. G., and Valiente, A. T., Effect of cooking and of amino acid supplementation on the nutritive value of black beans *(Phaseolus vulgaris, L)*, *Br. J. Nutr.*, 17, 69, 1963.
8. Munsell, H. E., Louis, O., Williams, L., Quild, P., Troescher, B., Nightingale, G., and Harris, R. S., Composition of food plants of Central America. I. Honduras, *Food Res.*, 14, 144, 1949.
9. Mc Coy, O. M., The nutritive value of potatoes, in *Potato Processing*, Talburt, W. F. and Smith, O., Eds., The Avi Publishing Co., New York, 1959, 187.
10. Jaraj, A. P., Joseph, K., Rao, M. N., Bhagavan, R. K., Swaminathan, M., and Subrahmanyan, U., Effect of varying levels of protein and calcium in the diet on the structure and composition of liver rats. I. The effect of supplementation of diets based on rice and rice-tapioca with calcium on the growth and structure and composition of liver of albino rats, *Ann. Biochem. Exp. Med.*, 20, 341, 1960.
11. Bressani, R., Elías, L. G., and Braham, J. E., Cottonseed protein in human foods, in *World Protein Resources.* A symposium sponsored by the Division of Agricultural and Food Chemistry at the 150th Meeting of the American Chemical Society, Atlantic City, N. J., Sept. 13-15, 1965, Altschul, A. M., Symposium Chairman, American Chemical Society, Washington, D. C., 1966, 75 (Advances in Chemistry Series 57).
12. Bressani, R., Jarquín, R., and Elías, L. G., Cottonseed flour. Free and total gossypol, epsilon amino lysine, and biological evaluation of cottonseed meals and flours in Central America, *J. Agric. Food Chem.*, 12, 278, 1964.
13. Anson, M. L., Potential uses of isolated oilseed protein in foodstuffs, in *Processed Plant Protein Foodstuffs*, Altschul, A. M., Ed., Academic Press, New York, 1958, 277.
14. Anson, M. L., Oilseed proteins in foods, *Arch. Biochem. Biophys.*, Supp. 1, 68, 1962.
15. Flodin, N. W., Amino acids and proteins. Their place in human nutrition problems, *J. Agric. Food Chem.*, 1, 222, 1953.
16. Almquist, H. J. and Grau, C. R., Mutual supplementary effect of the proteins of soybean and sesame meals, *Poult. Sci.*, 23, 341, 1944.
17. Waddel, J., Supplementation of plant proteins with amino acids, in *Processed Plant Protein Foodstuffs*, Altschul, A. M., Ed., Academic Press, New York, 1958, 307.
18. Allison, J. B., Wannemacker, R. W., Jr., and Mc Coy, J. R., The determination of the nutritive value of cottonseed flour, in *Proceedings of a Conference on Cottonseed Protein for Animal and Man, New Orleans, 1960*, U.S.D.A., New Orleans, April 1962, 1. (USDA, ARS 72-24).
19. Elías, L. G., Sánchez, S., and Bressani, R., Estudio comparativo de diferentes métodos para evaluación del valor proteínico de harinas de semilla de algodon, *Arch. Latinoamer. Nutr.*, 19, 279, 1969.

20. Braham, J. E., Elías, L. G., and Bressani, R., Factors affecting the nutritional quality of cottonseed meals, *J. Food Sci.*, 30, 531, 1965.
21. Elías, L. G. and Bressani, R., Amino acid and protein supplementation of defatted cottonseed flour, *Arch. Latinoamer. Nutr.*, 21, 149, 1971.
22. Krishnamorthy, K., Tasker, P. K., Ramakrishnan, T. N., Rajagopalan, R., and Swaminathan, M., Studies on the nutritive value of sesame seeds. I. The amino acids composition of the proteins and the chemical composition of sesame seeds and meal, *Ann. Biochem. Exp. Med.*, 20, 73, 1960.
23. Elías, L. G., Utilización de sub-productos ricos en proteínas, in *Recursos Proteínicos en América Latina*, Béhar, M. and Bressani, R., Eds., Memorias de una Conferencia de nivel latinoamericano celebrada en el Instituto de Nutrición de Centro América y Panamá (INCAP), ciudad de Guatemala, del 24 al 27 de febrero de 1970. Talleres Gráficos del INCAP, Guatemala, C. A., 1971, 396.
24. Liener, I. E., Effect of heat on plant proteins, in *Processed Plant Protein Foodstuffs*, Altschul, A. M., Ed., Academic Press, New York, 1958, 79.
25. Bressani, R. and Elías, L. G., Cambios en la composición química y en el valor nutritivo de la proteína de la harina de semilla de algodón durante su elaboración, *Arch. Latinoamer. Nutr.*, 18, 319, 1968.
26. Sakurei, Y. and Nakano, M., Production of high protein food from fermented soybean products, in Progress in Meeting Protein Needs of Infants and Pre-school Children, Proc. Internat. Conf., NRC Pub. 843, Washington, D.C., 1960, 251.
27. Elías, L. G. and Bressani, R., The nutritive value of the Brazil nut oil, *J. Oil Chem. Soc.*, 38, 450, 1961.
28. Squibb, R. L., Aguirre, A., and Bressani, R., African and Mbocayá palm meals as substitutes for sesame oil meal in baby chick rations, *Turrialba*, 8, 24, 1958.
29. Duckworth, J. and Woodman, A. A., Leaf protein concentrates. I. Effect of source of raw material and method of drying on protein value for chicks and rats, *J. Sci. Food Agric.*, 12, 5, 1961.
30. Cooke, B. B., Law, E. W., and Bailey, B. M., The protein quality of waste-grown green algae. I. Analysis of protein in mixtures of algae non-fat powdered milk and cereals, *J. Nutr.*, 81, 23, 1963.
31. Waterlow, J. E., The absorption and retention of nitrogen from leaf protein by infants recovering from protein malnutrition, *Br. J. Nutr.*, 16, 531, 1962.
32. Bressani, R. and Marenco, E., The enrichment of lime-treated corn with proteins, lysine and tryptophan, and vitamins, *J. Agric. Food Chem.*, 11, 517, 1963.
33. Elías, L. G. and Bressani, R., Valor nutritivo de la proteina de la levadura torula y como complemento de concentrados proteínicos, *Arch. Latinoamer. Nutr.*, 20, 135, 1970.
34. Allison, J. B., Biological evaluation of proteins, *Physiol. Rev.*, 35, 664, 1955.
35. Bressani, R., Elías, L. G., and Gómez Brenes, R. A., Improvement of protein quality by amino acid and protein supplementation, in *International Encyclopaedia of Food and Nutrition*, Bigwood, E. J., Ed., Vol. 11, Pergamon Press, Oxford, 1972, 475.
36. Clark, H. E., Allen, P. E., Meyers, S. M., Tuckett, S. N., and Yamamura, Y., Nitrogen balances of adults consuming Opaque-2 maize protein, *Am. J. Clin. Nutr.*, 20, 825, 1967.
37. Kies, C., Williams, E., and Fox, H. M., Determination of first limiting nitrogenous factor in corn protein for nitrogen retention in human adults, *J. Nutr.*, 86, 350, 1965.
38. Young, V. R., Ozalp, I., Cholakos, B. V., and Scrimshaw, N. S., Protein value of colombian Opaque-2 corn for young adult men, *J. Nutr.*, 101, 1475, 1971.
39. Bressani, R., The importance of corn for human nutrition in Latin America and other countries, in Proceedings of the Conference on Nutritional Improvement of Corn, Institute of Nutrition of Central America and Panama (INCAP), Guatemala, 1972.
40. Elías, L. G. and Bressani, R., Nutritional value of the protein of tortilla flour and its improvement by fortification in Central America, in Proceedings of the Conference on Nutritional Improvement of Corn, Institute of Nutrition of Central America and Panama, (INCAP), Guatemala, 1972.
41. Matoth, Y., Elian, E., and Gruenberg, E., Evaluation of a protein-rich mixture based on vegetable foods of middle eastern countries, *Am. J. Clin. Nutr.*, 21, 226, 1968.
42. Bressani, R., Formulation and testing of weaning and supplementary foods containing oilseed proteins, in *Protein-Enriched Cereal Foods for World Needs*, Milner, M., Ed., Am. Assoc. Cereal Chemists, St. Paul, Minn., 1969, 49.
43. Parpia, H. A. B., Protein foods of India based on cereals, legumes and oilseed meals, in *Protein-Enriched Cereal Foods for World Needs*, Milner, M., Ed., Am. Assoc. Cereal Chemists, St. Paul, Minn., 1969, 129.
44. Senti, F. R., Formulated cereal foods in the U.S. Food for peace program, in *Protein-Enriched Cereal Foods for World Needs*, Milner, M., Ed., Am. Assoc. Cereal Chemists, St. Paul, Minn., 1969, 246.
45. Bressani, R., Application of food science and technology to the exploitation of new protein sources, in *Proceedings Western Hemisphere Nutrition Congress III*, August 30-September 2, 1971, Miami Beach, Fla., Futura Publishing Co., Mount Kisko, N.Y., 1971, 368.
46. Elder, A. and Weisber, S. M., High nutrition - low cost foods; their impact in developing countries, in Proceedings of the III International Congress of Food Science and Technology, SOS/70, Washington, D.C., 1970.

47. FAO/WHO/UNICEF Protein Advisory Group, *PAG Guideline on Mixtures for Use on Weaning Foods*, Protein Advisory Group of the United Nations System, United Nations, New York, 1971 (PAG Guideline No. 8).
48. FAO/WHO/UNICEF Protein Advisory Group, *Human Testing of Supplementary Food Mixtures*, FAO/WHO/UNICEF Protein Advisory Group, United Nations, New York, 1970 (PAG Guideline No. 7).
49. Viteri, F. E. and Bressani, R., The human testing of new sources of protein with emphasis on protein quality, *Bull. WHO*, in press.
50. FAO/WHO/UNICEF Protein Advisory Group, *Edible Heat Processed Soy Grits and Flour*, FAO/WHO/UNICEF Protein Advisory Group, United Nations, New York, 1969 (PAG Guideline No. 5).
51. FAO/WHO/UNICEF Protein Advisory Group, *Preparation of Edible Cottonseed Protein Concentrate*, FAO/WHO/UNICEF Protein Advisory Group, United Nations, New York, 1970 (PAG Guideline No. 4).
52. FAO/WHO/UNICEF Protein Advisory Group, *Preparing Food Quality Groundnut Flour*, FAO/WHO/UNICEF Protein Advisory Group, United Nations, New York, 1970 (PAG Guideline No. 2).
53. Bressani, R., Elías, L. G., and Braham, J. E., Suplementacion, con aminoácidos, del maíz y de la tortilla, *Arch. Latinoamer. Nutr.*, 18, 123, 1968.
54. Elías, L. G., Jarquín, R., Bressani, R., and Albertazzi, C., Suplementación del arroz con concentrados proteicos, *Arch. Latinoamer. Nutr.*, 18, 27, 1968.
55. Elías, L. G. and Bressani, R., Valor proteínico de los subproductos de la industria del trigo. II. Complementación y suplementación del granillo de trigo con concentrados proteínicos, *Arch. Latinoamer. Nutr.*, to be published.
56. Ranhotra, G. S., Supplemental effect of wheat-protein-concentrate upon the protein quality of white wheat flour, in *Proceedings Western Hemisphere Nutrition Congress III*, August 30-September 2, 1971, Miami Beach, Fla., Futura Publishing Co., Mount Kisko, N.Y., 1971, 378.
57. Hedges, N. J. and Tinklin, G. L., Chapatti quality as affected by wheat protein concentrate, *Cereal Sci. Today*, 14, 344, 1969.
58. Tosello, A., Consideracoes nutricionais na formulacao de farinhas de trigo com outras farinhas, in *Recursos Proteínicos en América Latina*, Béhar, M. and Bressani, R., Eds., Memorias de una Conferencia de nivel latinoamericano celebrada en el Instituto de Nutrición de Centro América y Panamá (INCAP), ciudad de Guatemala, del 24 al 27 de febrero de 1970. Talleres Gráficos del INCAP, Guatemala, C.A., 1971, 388.
59. Kim, J. C. and De Ruiter, D., Bread from non-wheat flour, *Food Technol.*, 22, 867, 1968.
60. Bacigalupo, A., Protein-rich cereal foods in Peru, in *Protein-Enriched Cereal Foods for World Needs*, Milner, M., Ed., Am. Assoc. Cereal Chemists, St. Paul, Minn., 1968.
61. Dutra de Oliveira, J. E. and Da Silva, L. P., Valor nutritivo de milho Opaco-2 e de mixturas do milho hibrido e Opaco-2 producidos no Brasil. Resumen de temas libres presentados en la I Reunión Científica de la Sociedad Latino Americana de Nutrición, Caracas, Venezuela, 1968.
62. Dutra de Oliveira, J. E. and Menezes Salata, E. B. Z., Methionine fortified manioc flour to combat protein malnutrition, *Nutr. Rep. Int.*, 3, 291, 1971.
63. Elías, L. G. and Bressani, R., unpublished data.
64. Arroyave, G., Distribution of vitamin A to population groups, in *Proceedings Western Hemisphere Nutrition Congress III*, August 30-September 2, 1971, Miami Beach, Fla., Futura Publishing Co., Mount Kisko, N.Y., 1971, 68.
65. Levison, F. J. and Berg, A. D., With a grain of fortified salt, *Food Technol.*, 23, 1174, 1969.
66. Parpia, H. A. B., Food technology problems in India and other developing countries, *Food Technol.*, 22, 62, 1968.
67. Chandrasekhara, M. R., Shurpalekar, S. R., Rao, B. H. S., Kurien, S., and Shurpalekar, K. S., Development of infant foods based on soybean, *J. Food Sci. Technol.*, 3, 94, 1966.
68. Hang, Y. D. and Jackson, H., Preparation of soybean cheese using lactic starter organisms. I. General characteristics of the finished cheese, *Food Technol.*, 21, 1033, 1967.
69. Hang, Y. D. and Jackson, J., Preparation of soybean cheese using lactic starter organisms. II. Effect of addition of rennet extract and skimmilk, *Food Technol.*, 21, 1035, 1967.
70. Loewnstein, M. and Paulraj, V. K., Preparation and growth producing evaluation of a concentrated coprecipitate of soy-cheese whey protein, *Food Prod. Dev.*, 5, 56, 1972.
71. Lawhon, J. T., Cater, C. M., and Mattil, K. F., Preparation of a high-protein low-cost nut-like food product from glandless cottonseed kernels, *Food Technol.*, 24, 701, 1970.
72. Lawhon, J. T., Cater, C. M., and Mattil, K. F., Influence of the deep-fat frying medium on the acceptability and stability of glandless cottonseed kernels for use as a high-protein, low-cost edible nut, *Food Technol.*, 24, 817, 1970.
73. Pominski, J., Pearce, H. M., Jr., and Spadaro, J. J., Partially defatted peanuts – factors affecting oil removal during pressing, *Food Technol.*, 24, 716, 1970.
74. Mustakas, G., Albrecht, W. J., Book Walter, G. N., McGhee, J. E., Kwolek, W. F., and Griffin, E. L., Jr., Extruder-processing to improve nutritional quality flavor and keeping quality of full fat soyflour, *Food Technol.*, 24, 1290, 1970.
75. Hand, D. B., Steinkraus, K. H., Van Bureau, J. P., Hackler, L. R., Rawis, I., and Pallesen, H. R., Pilot plant studies on soy milk, *Food Technol.*, 18, 139, 1964.

76. Wilkens, W. F., Mattick, L. R., and Hand, D. B., Effect of processing method on oxidation off-flavors of soybean milk, *Food Technol.*, 21, 1630, 1967.
77. Thulin, W. W. and Kuramoto, S., Bontrae a new meat-like ingredient for convenience foods, *Food Technol.*, 21, 168, 1967.
78. Johnson, D. W., Oilseed proteins. Properties and applications, *Food Prod. Dev.*, 3, 78, 1970.
79. Bressani, R., Viteri, F. E., Elias, L. G., Zaghi, S. de, Alvarado, J., and Odel, A. D., Protein quality of a soybean protein textured food in experimental animals and children, *J. Nutr.*, 93, 349, 1967.
80. Mertz, F. T., Bates, L. S., and Nelson, E. R., Mutant gene that changes protein composition and increases lysine content of maize endosperm, *Science*, 145, 279, 1964.
81. Kies, C. and Fox, H. M., Interrelationships of leucine with lysine, tryptophan, and niacin as they influence protein value of cereal grains for humans, *Cereal Chem.*, 49, 223, 1972.
82. Bressani, R., Elias, L. G., and Gómez Brenes, R. A., Protein quality of Opaque-2 corn evaluation in rats, *J. Nutr.*, 97, 173, 1969.
83. Bressani, R., Alvarado, J., and Viteri, F. E., Evaluación en niños de la calidad de la proteina del maiz Opaco-2, *Arch. Latinoamer. Nutr.*, 19, 129, 1969.
84. Miravalle, R. J., The plant geneticists' contribution toward changing the lipid and amino acid composition of cottonseed, *J. Am. Oil Chem. Soc.*, 49, 15, 1972.
85. Knowless, P. F., The plant geneticists' contribution toward changing lipid and amino acid composition of safflower, *J. Am. Oil Chem. Soc.*, 49, 27, 1972.
86. Howell, R. W., Brim, C. A., and Rinne, R. W., The plant geneticists' contribution toward changing lipid and amino acid composition of soybeans, *J. Am. Oil Chem. Soc.*, 49, 30, 1972.
87. Sebrell, W. H., Enrichment: good gift of yesterday, *Cereal Sci. Today*, 11, 228, 1966.