World Needs for Improved Nutrition and the Role of Vegetables and Legumes

Ricardo Bressani

10th Anniversary Monograph Series
Asian Vegetable Research and Development Center

Correct Citation:

Bressani, Ricardo. 1983. World Needs for Improved Nutrition and the Role of Vegetables and Legumes. Asian Vegetable Research and Development Center, 10th Anniversary Monograph Series. Shanhua, Taiwan, Republic of China.

AVRDC Publication 83-185

World Needs for Improved Nutrition and the Role of Vegetables and Legumes

Ricardo Bressani[1]

Hunger and malnutrition have been man's constant companions throughout his development, and the history of man has been the history of the fight for food. In the past, however, population pressure was appreciably lower than it is today. Likewise productive land was available as well as bountiful game and native vegetables. Although the problems of hunger and malnutrition existed, they first received attention in medical journals and in news reports about 40 years ago. Around 1950 the words "kwashiorkor" and "marasmus" became part of the language of many professionals in the disciplines of medicine and biochemistry. The first term describes the effects of malnutrition caused by high energy, low protein quantity and quality intake associated with deficiencies of other nutrients. The term marasmus, biochemically different from kwashiorkor, describes the condition resulting from low energy and protein intake (28). These conditions represent the extreme cases of the problem, but leading to those extremes are abundant cases of child malnutrition classified as 1st, 2nd, and 3rd degree (28). Children suffering from any degree of malnutrition, even those not as acute as kwashiorkor or marasmus, do not develop to their full weight and height potential and often suffer from mental retardation. This phenomenon represents a weight on society and undermines the scientific and technological advances made in the last 15-20 years.

Why are hunger and malnutrition so difficult to eradicate? At first these problems were thought to be medical. With time,

---

[1] Head. Division of Agricultural and Food Sciences, Instituto de Nutricion de Centro America y Panama.

however, it was recognized that hunger and malnutrition were the results of a number of factors and could only be resolved through a concerted interdisciplinary effort. One of the most important factors is agricultural production and the availability of food. It must be emphasized, however, that agricultural production per se cannot resolve these problems. There is need for action in education and economic development as well as in public health and environment. Within the socioeconomic aspect of the problem, poverty is a significant component of malnutrition. Low-cost foods consumed by the poor are usually of poor nutritional value. Thus the foods which low-income people consume should be of the best possible nutritive value and be consumed in appropriate combinations.

Malnutrition in the Developing World

Based on a number of reports from the World Health Organization, the major worldwide nutritive deficiencies are iron, iodine, protein, calories, and vitamin A (24,35,36,37). The names of the most common deficiencies, the nutrients responsible, and the resulting symptoms are shown in Table 1. Iron deficiency causes

Table 1. Major nutritional deficiencies in humans.

	Deficiency in:	Symptoms:	Food items lacking:
Anemia	Iron	Insufficient haemoglobin - pale skin, fatigue, reduced working capacity, reduced resistance to infection	Red meat, liver, cereals, fruits, green vegetables
Goiter	Iodine	Swollen thyroid - deformation of throat mental retardation	Fish sea food
Kwashiorkor	Protein	Generalized edema - retardation of growth and development, apathy	Dairy products, meat, fish, eggs, legumes
Marasmus	Calories	"Skin and Bones" - retardation of growth and development	Mother's milk cereals tubers fats
Xerophtalmia	Vitamin A	"Dry eyes" - night blindness (retina) blindness (cornea, conjuntiva)	Dairy products vegetables fruits

anemia in the individual as measured by low hemoglobin levels, reduced resistance to infection, reduced work capacity, fatigue, dullness of the hair, and pale skin. Animal food products are good sources of iron, but cereals, fruits, and green vegetables can also provide important amounts of this nutrient.

The deficiency disease induced by a lack of iodine is known as goiter. The symptoms are deformation of the throat by an enlarged thyroid and, in some cases, mental retardation. As indicated in the previous section, a protein quantity and quality deficiency includes kwashiorkor with symptoms such as generalized edema, retardation of growth and development, and apathy. On the other extreme, a deficiency of calories leads to the deficiency disease known as marasmus, which in children leads to retardation of growth and development and severe weight loss. Finally, xerophthalmia is induced by a deficiency of vitamin A with such symptoms as dry eyes, night blindness, and overall blindness.

Malnutrition affects all members of the family, but poor diets have the greatest impact on children and pregnant and lactating women. An appropriate intake of energy and high quality protein foods properly reinforced with fruits and vegetables is extremely important during the weaning process as there is less dependence on mother's milk.

It is important to realize, however, that the body needs a combination of nutrients. Although a particular deficiency may be attributed to one nutrient, other nutrients may also be deficient or marginal, or poorly utilized because of a single deficiency of the one nutrient. An example of one nutrient that affects others is vitamin C, which increases iron absorption (8,16,27), and the utilization of vitamin A (19,31), leucine, niacin (15), protein, and calcium (30).

From dietary surveys and food composition tables, it becomes apparent that a diet made up mainly of vegetables and other plant crops can supply all the needed nutrients, with the exception of vitamin B_{12}. An example of rural diets in Central America is shown in Table 2. The data indicate that such diets can provide

Table 2. Percentage contribution of food groups to the average nutrient intake in rural Guatemala.

	Cals	Prot	Ca	Fe	Vit A	B_1	B_2	Niac	Vit C
Animal food products	8.1	23.5	18.0	13.0	33.6	10.5	47.2	14.3	0
Food legumes	8.5	18.7	6.6	24.7	0.6	21.9	9.7	9.3	0
Vegetables	1.0	1.7	2.7	2.1	37.4	1.0	1.4	3.9	58.8
Fruits	2.1	0.6	0.5	0.7	11.3	1.0	1.4	2.1	35.3
Tubers	0.7	0.4	0.2	0.7	0	1.0	0	1.6	5.9
Cereals	65.0	52.6	68.8	50.7	15.4	61.9	36.1	54.0	0
Sugars	10.9	0.1	1.1	4.4	0	0	2.8	0.4	0
Fat & oils	3.6	0	0	0	0	0	0	0	0
Other (coffee)	1.2	2.3	2.0	3.4	1.7	2.9	1.4	14.3	0

ample amounts of all nutrients and are more complete if small amounts of animal food products are also consumed (17). The disadvantages of vegetable-based diets, particularly for small children, are the bulkiness of the diet that limits intake, the fact that many vegetable foods contain antiphysiological substances that interfere with the biological utilization of nutrients, and the incomplete availability of specific nutrients to the animal organism (11,12,20,21).

Food Supply and Diet

The problems of hunger and malnutrition are obviously not simple. Biological, technological, social, cultural, economic, political, and even moral aspects must be taken into consideration. The basic factor, however, is the food supply and its capacity to meet not only the population's needs for food but its nutritional well-being.

The concept of food supply in a particular area is made up of three critical aspects - quantity, quality, and distribution or availability. Furthermore, the food supply, in terms of the objective of providing good nutrition to the population, should not be viewed as single, independent groups of commodities, as is often the case, but as components of the diets people consume. The nutrients of each food component should complement or supplement each other to provide the nutrients needed for each physiological stage of the individual's development, for the individual's activities particular to each of these stages, and for situations of stress in the individual's life.

The quality of the diet in terms of the food supply is then the result of a complex multifactorial equation: diet quality index = production x quality x availability. Production itself is related to income. The production component of the equation obviously refers to quantity, which is affected by such factors as the genetic make-up of the plant or animal, disease resistance, management and agronomic practices, and environmental conditions. These factors primarily affect production, but they also affect quality. The quality component of the equation is made up of at least two factors, one of which is the technological properties of the food. The second factor is the nutritional value of the food as a part of the diet. The technological properties, dependent on the chemical components of the food and controlled by production factors, involve aspects of storage, processing, and functionality. Nutritional value is affected by the content and physiological availability of nutrients, which, in turn, are dependent on production and technological factors. Distribution and/or availability is also made up of at least two components. The first is physical in nature, namely how much reaches the stomach, and the second is related to the capacity of the individual to utilize the nutrients that reach the stomach. This last aspect has to do with environmental effects on the individual and his physiological functions. The significance of production, quality, and availability of foods for improved nutrition will be discussed in the following sections.

Agricultural research centers should include in their scope of activities the nutritional quality and acceptability of the product to the consumer. In addition, strong and versatile home extension programs should be implemented to achieve the fruits of agricultural research.

Food Consumption Systems

Dietary surveys reveal that the basic diet in most parts of the world is made up of relatively large amounts of cereal grains with smaller but important quantities of food legumes. Other food items include small amounts of animal products and somewhat larger amounts of vegetables and fruits, tubers, sugar, oil, and beverages. In various regions, tubers such as cassava and yams replace the cereal grains and make up the bulk of the diet. Because the intake of cereal grains is relatively high, they provide significant amounts of nutrients to the diet (17) (Table 2). Quality, however, particularly of protein, decreases their net value in the diet unless other items are consumed. The table shows that food legumes and animal food products also provide additional amounts of nutrients which complement those provided by the cereal grains. Since animal food products are expensive, more dependence on food legumes is necessary, although small amounts of animal products can be of great importance to the quality and acceptability of the diet.

Cereal and food legume consumption patterns provide useful systems for production programs and for selection and recommendations of supplementary foods. For this purpose three systems will be discussed: maize/bean, rice/bean, and cassava/bean.

The Maize/Bean System

Figure 1 shows the results of several studies representing the maize/bean consumption system (5), a dynamic system that determines at each point what other foods are to be consumed with maize and beans to reach a desired nutritional level. The system also shows the importance and the implications of animal products and the foods or nutrients necessary for the improvement of the nutritional value of the basic maize and bean diet. In the figure, optimum protein quality is shown by two lines. One represents common maize and beans, and descends on both sides of the maximum point which corresponds to a 70/30 proportion by weight. The second represents the response of high quality protein maize and beans. It also has a maximum value of 70/30, but, unlike the former, the response is constant on the side of the high protein maize.

Present maize and bean consumption in Guatemala is represented by point A with the nutritive value B. This value can increase to the nutritive value F as bean consumption is increased to point E. To go from point A to point E, higher bean production and availability are required. From point B to point D or

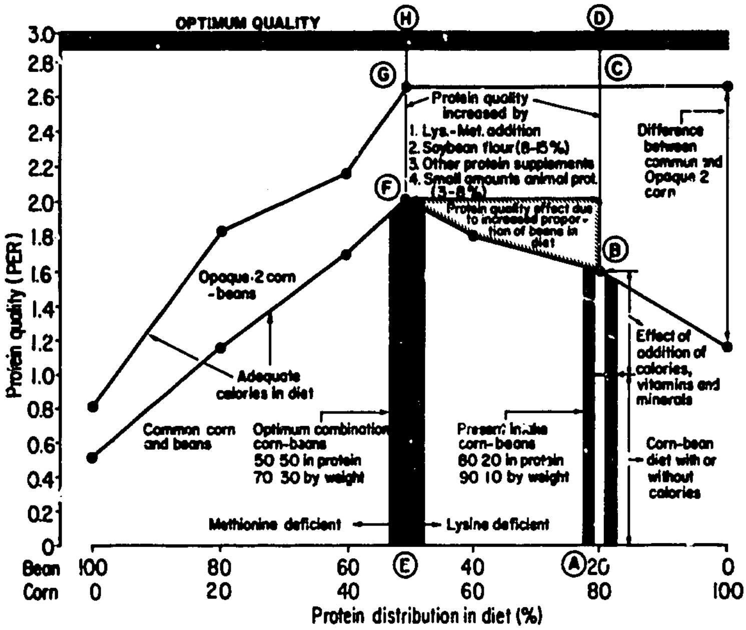

Figure 1. The corn/bean consumption system and ways to improve its nutritional value.

from point F to point H it is necessary to increase the consumption levels of high protein foods.

As the figure indicates, shifts from point B to point C or from point F to point G can be attained by replacing common maize with higher protein maize. One point of particular interest is that the cost and the implications of going from F or G to H are much lower than from quality B or C to D, and, in each case, it is more economical to go from G to H or C to D with high protein maize in the diet rather than common maize.

The data in Figure 1 were obtained in experiments based on the constant and continuous availability of both maize and beans. Table 3 demonstrates the point and indicates the need for obtaining sufficient production to guarantee higher availability. This table represents a model for the study of the effect of bean intake frequency on a constant intake of maize. As the data in the column on the left shows, the response increases as bean consumption frequency increases. The data in the column on the right, obtained when both foods were given simultaneously in different proportions, show that with a low but continuous and daily bean intake, a good response can be obtained. Translating this again to agricultural production, it is important to maintain the availability of beans. The beans, however, must provide the characteristics desired by the consumer, as well as the best nutritive qualities possible.

Ascribing all of the nutritional responsibility to a single agricultural product, however, is both difficult and undesirable.

Table 3. Effect on animal performance of frequency of bean intake on a basal diet of maize.

Frequency of bean intake	Maize + Beans fed separately		Maize + Beans fed together	
	Avg. wt. gain (g)	Carcass N (g)	Avg. wt. gain (g)	Carcass N (g)
Maize alone	46	2.47	44	2.54
For 12 days	74	3.17	105	4.48
For 20 days	75	3.23	103	4.51
For 26 days	103	4.02	103	4.45

Therefore, the importance of the frequency of consumption of a certain food can be lower if the base food of the diet is of better nutritive value (Table 4). The experimental model utilized is the same as before, but here one base food is common maize (left side of the table) and the other is high protein maize (right side). The common maize data on the left emphasize that a better response is obtained when the frequency of bean intake is increased. For the high nutritive value maize, the bean intake frequency is not important. In other words, an alimentary base of high nutritive value reduces the pressure for supplementary foods and represents insurance against the absence of complementary foods in the diet.

Table 4. Effect of bean intake on a basal diet of common and high protein maize.

Frequency of	Common maize		High protein maize	
	Avg. wt. gain (g)	Carcass N (g)	Avg. wt. gain (g)	Carcass N (g)
for 0 days	46	2.47	95	4.49
12 out of 28 days	74	3.17	98	4.74
20 out of 28 days	75	3.23	93	4.41
for 28 days	103	4.02	97	5.14

Bressani and Elías, 1979.

The Rice/Bean System

The information shown in Figure 2 for rice and beans was obtained in the same fashion as that of the maize/bean system. In

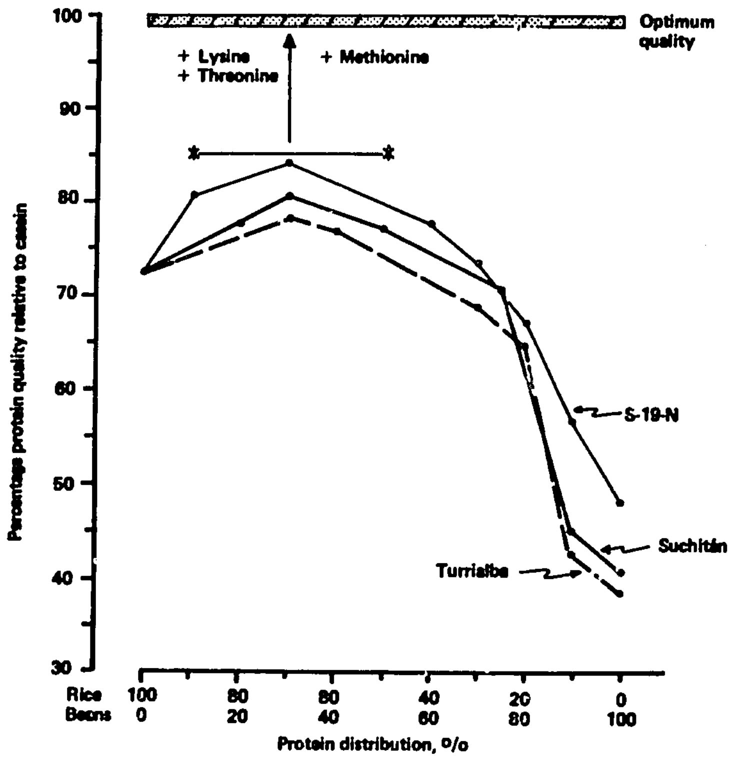

Figure 2. The rice/bean system.

this example, bean cultivars were complemented with one variety of rice. The figure shows, as with maize and beans, a point of maximum protein quality when 70% of the protein of the diet is derived from rice and 30% from beans. These percentages would be equivalent to 88 g of rice and 12 g of beans. Although the 70/30 mixture shows a peak value, it should be noted that protein values from 90 to 40% for rice and from 10 to 60% for beans were statistically alike (2,33). It is clear, therefore, that increased bean intake provides a diet of the same quality but higher in protein than the one in which rice predominates, since beans contain about three times more protein than rice. Again, these results suggest the importance of increasing bean production to increase availability at the home level. The second point of interest in this figure is that the peak value was higher for one cultivar than for the other two. This suggests that beans of higher protein quality can be selected for production to better complement cereal grains. The 100% quality line can be reached through the consumption of foods that are good sources of sulfur amino acids and threonine. The sulfur amino acids will have a limiting effect as the amount of beans predominates, while lysine and threonine will limit the protein quality of the diet as rice protein predominates (2).

Other Cereal/Food Legume Systems

Food consumption systems based on a cereal grain and a food legume, other than those already discussed, exist in other regions of the world. Figure 3 shows the complementary effect of combinations of mungbeans and rice as evaluated by two different laboratories (1,23). In both situations a peak value results when 25 and 75% of the dietary protein comes from mungbean and rice, respectively, with a quality value of around 92% that of casein. On a weight basis, the ratio indicated in the figure corresponds to 12% mungbean and 88% rice. Food balance sheets for India, Indonesia, Taiwan, Thailand, Korea, and the Philippines indicate that the current legume to cereal protein ratios are 26:74, 25:75, 20:80, 14:86, 11:89, and 6:94, respectively (1). Some of the theoretical ratios from the food balance sheets are close to the optimum ratio, but those with a higher contribution from mungbeans will be limited in their nutritive value by sulfur amino acids, while those where rice predominates will be limited by lysine and threonine.

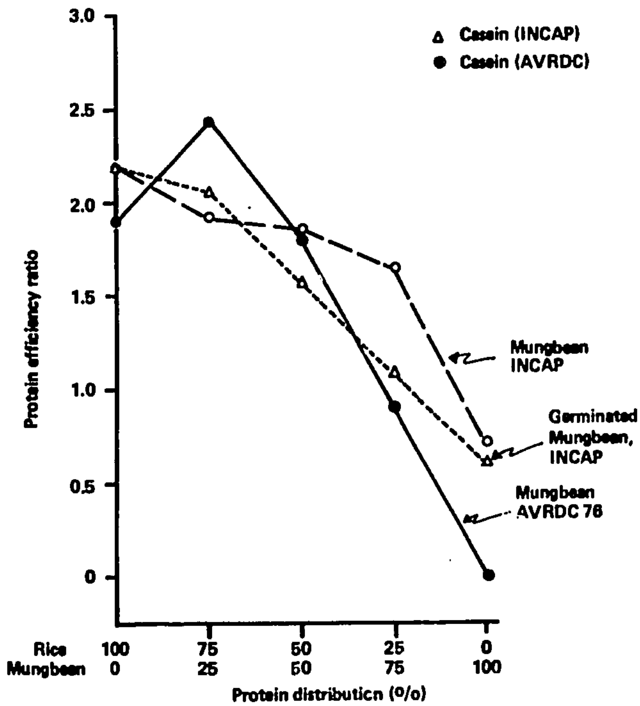

Figure 3. The rice/mungbean system.

Faba beans and wheat also complement each other (Figure 4) with a maximum response at a weight ratio of 3:7 (6). The quality of the best response is rather high, approaching values for casein. The results in Table 5 clearly demonstrate the effects of

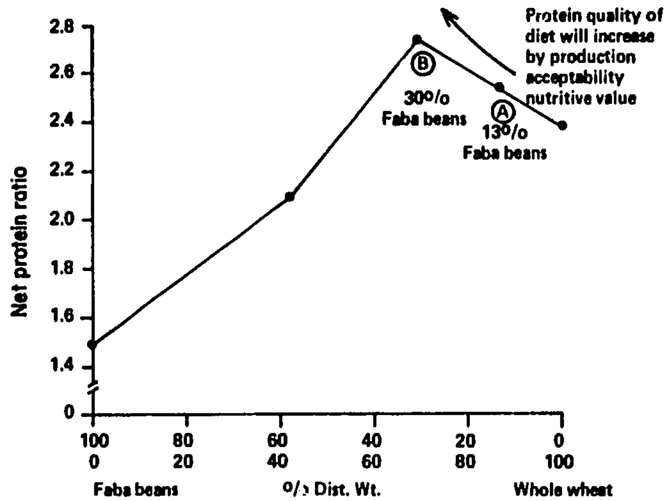

Figure 4. Protein quality of mixtures of faba beans and whole wheat and significance of increased production, acceptability, and nutritive value.

Table 5. Protein quality improvement of the wheat/faba bean mixture (7:3) by amino acid supplementation.

Treatment	Weight gain g/14 days	Net protein ratio[4]
Faba beans	8	1.62
Faba beans + Methionine[1]	53	3.19
Whole wheat	26	1.93
Whole wheat + Lysine[2]	46	2.55
Wheat/faba bean mixture (7:3)	38	2.76
Wheat/faba bean mixture (7:3) + Methionine[3] + Lysine[2]	56	3.05
Casein (control)	65	3.91

[1] 0.3% DL-Methionine.
[2] 0.2% L -Lysine HCl.
[3] 0.2% DL-Methionine.
[4] Mean values for eight rats (four male and four female) per group.

adding limiting amino acids to wheat, to faba beans, and to the 3:7 mixture. Wheat responded to lysine and faba beans responded to methionine addition, as would be expected, while the optimum mixture responded to the addition of both amino acids (6). Another example of a food system is sorghum and cowpeas (Table 6) (3). In this case, as in previous systems, there is also a point of maximum response, and the limitations governing this system are similar to those already explained.

Table 6. Protein quality of mixtures of sorghum and cowpea.

Protein distribution in diet		PER
Sorghum	Cowpea	
100	0	1.22
75	25	1.59
50	50	1.84
25	75	1.82
0	100	1.41

These systems, if practiced, would represent a good beginning for improved nutrition as far as calories and protein quality and quantity are concerned. Although they represent an improved situation, it is desirable nonetheless to optimize them in other nutrients as well.

The Starchy Food Crop/Bean System

Food consumption surveys carried out in various regions of the world show that when cereals are not readily available, starchy foods take their place. Although cassava is probably the most important, other starchy foods such as yams and plantains are also consumed. These foods are characterized by low protein concentrations and high carbohydrate content. The supplementary role of food legumes in diets based on such high carbohydrate foods has been studied and the results are shown in Table 7 (7). In

Table 7. Average weight gain of rats fed different root crops and beans with and without methionine.

Level of beans in diet (%)	Weight (g)					
	Cassava		Yam		Plantain	
	-Met	+Met	-Met	+Met	-Met	+Met
0	-13.5	-	-14.5	-	-11.6	-
10	- 6.6	0	-10.6	3.6	- 1.2	7.5
20	9.1	43.4	- 1.7	31.5	10.9	46.1
30	22.0	74.4	5.6	56.7	34.2	80.6
40	34.4	105.9	22.5	85.2	58.8	101.2

these studies beans were not supplemented with methionine in one case and methionine was added in the second. The levels of beans added to 60% of the starchy food flour were 0, 10, 20, 30, and 40%. When beans were not supplemented with methionine, weight gain became positive with 20% beans for cassava and plantain, and 30% for yam. Weight gain at the level of beans giving positive gains was about 9, 6, and 11 g, respectively, in 28 days. The same levels of beans with added methionine produced weight gains of 43, 57, and 46 g, respectively. These systems are therefore extremely poor in terms of protein unless consumption of food legumes is high or the beans contain higher levels of sulfur amino acids. Recent studies show that adult human subjects require about 120 mg of bean nitrogen/kg/day to be in nitrogen equilibrium when beans are supplied along with cassava or plantain (22). These figures correspond to 0.76 g protein/kg/day, or 3.3 g beans/kg/day. The average weight of the subjects was 54 kg, indicating a daily bean intake of 178 g. This amount is quite high and difficult to obtain. The starchy food/bean system is therefore one which would benefit extensively from food legumes with higher sulfur amino acid content or combinations of other foods that contain high amounts of these amino acids.

The patterns of the cereal or starchy crops/food legume consumption systems are useful for agricultural policies concerning production and storage of the basic staples. Thus, breeding programs should increase the production and availability of staples to allow people to achieve the optimum level of consumption as a safety factor or insurance for good nutrition. The systems also provide useful information on the needed nutrients breeding programs should consider to improve quality. Furthermore, they show the nutrients needed from other sources to increase quality. It should be noted that selection programs for quality nutrition should be done on the basis of the nutritional quality of the mixture of the components rather than on the individual cereal grains or food legumes. Finally, it must be emphasized that the optimum point is the result of a better amino acid balance, which implies higher intakes of the two basic foods and a higher demand for other nutrients such as vitamins and minerals. The necessary additional quality protein, minerals, and vitamins can be obtained from small amounts of animal food products. Vegetables, however, can also provide these nutrients.

Nutritional Role of Vegetables

Vegetables are excellent sources of vitamins, particularly niacin, riboflavin, thiamine, and vitamins A and C. They also supply minerals such as calcium and iron, although in some instances these are not completely available to the animal organism (14). Vegetables represent almost any edible part of a herbaceous plant. For the purpose of this paper, attention will be given mainly to leaves, particularly those consumed by rural populations in developing countries.

Leaves are more attractive chemically and nutritionally than most other plant parts except for the seed. They are, however, low in dry matter content - an important source of concentrated nutrients (representative values are shown in Table 8). Leaves have relatively high vegetable protein and crude fiber contents. The latter may also be a useful nutritional attribute for western type diets that are characterized by low fiber content. Table 9 shows the essential amino acid content of a number of native vegetables consumed in Guatemala (9,13). Their amino acid pattern shows some interesting points. For example, lysine content is relatively high, which implies that it is a good supplement to cereal grains. A common food in rural Guatemala is a lime-treated maize dough in the shape of a ball containing chipilin (<u>Crotalaria longirostrata</u>) which, as shown in the table, contains high amounts of lysine, the amino acid limiting maize protein quality. Sulfur amino acid content is quite low, a factor already well known for leaf protein (29,34). The table also shows differences in the crude protein content as well as in the true protein content of the vegetables analyzed. The true protein represents about 77% of the crude protein content.

Table 8. Partial chemical composition of selected leafy vegetables (%).

Vegetable	Protein	Crude fat	Crude fiber	Ash
Chard	15.6	3.9	9.8	15.6
Watercress	32.3	4.6	12.7	15.0
Amaranth	23.8	5.1	9.6	13.5
Crotalaria	34.2	3.9	9.8	7.3
Brussels sprouts	28.0	1.6	10.2	7.0
Spinach	20.9	1.6	4.6	15.6
Lettuce	21.4	2.1	10.7	8.6

Table 9. Amino acid pattern, crude and true protein of some vegetables consumed in Central America compared with the FAO pattern.

Amino Acid	Bledo (Amaranth)	Macuy	Chipilin (Crotalaria longirost.)	Puntas de Guisquil	Berro (Watercress)	Ejotes (Green beans)	Germ. Soybean	FAO
Valine	4.77	4.27	5.00	3.84	4.87	4.16	4.37	4.96
Threonine	2.87	2.76	3.00	2.45	2.76	2.71	2.04	4.00
Total Sulfur AA	1.29	1.18	0.82	1.17	0.75	1.13	1.38	3.52
Isoleucine	2.30	2.04	2.19	1.83	2.22	1.88	1.94	4.00
Leucine	8.11	7.59	8.31	7.09	6.85	5.84	5.80	7.04
Total Aromatic AA	7.57	7.54	7.33	6.27	6.38	4.75	6.75	6.08
Lysine	7.62	7.11	8.17	5.83	6.18	5.46	6.19	5.44
Histidine	2.52	3.38	3.56	2.32	3.04	2.50	3.44	----
Arginine	4.77	3.91	4.12	4.36	3.94	2.89	6.82	----
Crude protein (N x 6.25)	28.20	31.20	32.50	40.50	32.80	21.10	39.30	----
True protein	23.70	25.00	26.90	28.60	25.70	14.50	29.40	----

The low concentration of sulfur amino acids in leaves consumed as vegetables is shown in Table 10 for amaranth and C. longirostrata (34). As indicated, the addition of methionine increases protein quality about 79%. However, vegetables are

Table 10. Protein quality and effect of various local vegetables and effect of methionine supplementation.

Vegetable	Avg. wt. gain (g)	PER
Amaranthus	10	1.05
Amaranthus + 0.2% DL-Met	37	1.88
Crotalaria longirostrata	27	1.37
Crotalaria longirostrata + 0.2% DL-Met	68	2.46

Elías & Bressani, 1978.

seldom used as protein sources, although they can be used to produce juices and protein concentrates. Their primary nutritional role is their contribution of vitamins to the diet. Although evaluations of the nutritional role of vegetables are difficult to carry out, since they must be long term or use biochemical evaluations, some results are shown in Table 11. In this case a basal diet of 90% maize and 10% common beans was supplemented with 5% dehydrated amaranth leaves. The basal diet in one case was supplemented with vitamins and minerals; in the second these nutrients were left out. In the first case, in the presence of vitamins and minerals, protein quality increased from a PER value of 1.84 to 2.32, reflecting better animal performance. The same was evident in the second case when the basal diet did not receive vitamins and minerals. The gains, however, were somewhat lower in this case than in the first. These data were interpreted to mean that the 5% amaranth leaf meal provided some of the vitamins and minerals missing from the basal maize/bean diet. However, as indicated in the maize/bean consumption system of Figure 1, this diet is probably limited in lysine, and some of the increment in animal performance could also have been due to this nutritional factor. A similar experiment with spinach, a better known vegetable, is shown in Figure 5. The addition of 5% spinach-leaf meal to the 90/10 maize/bean diet, supplemented with vitamins and minerals, induced a significant weight increase. A lesser increase was noted when the basal diet was not supplemented with vitamins and minerals (18). Therefore, this type of vegetable can be of great value in helping to meet nutritional needs.

Table 11. Effect of the supplementation of a basal diet[1] with 5% amaranth leaves.

Dietary treatment	Avg. wt. gain (g)	Avg. feed intake (g)	PER[2]
Basal diet (+ Vit + Min)	58	337	1.84
Basal diet (+ Vit + Min) + Amaranth leaves	100	420	2.32
Basal diet (- Vit - Min)	37	268	1.48
Basal diet (- Vit - Min) + Amaranth leaves	67	327	1.96

[1] Basal diet (90% maize + 10% common beans).
[2] PER = Avg. weight gain/Avg. protein consumed.
Elias & Bressani, 1978.

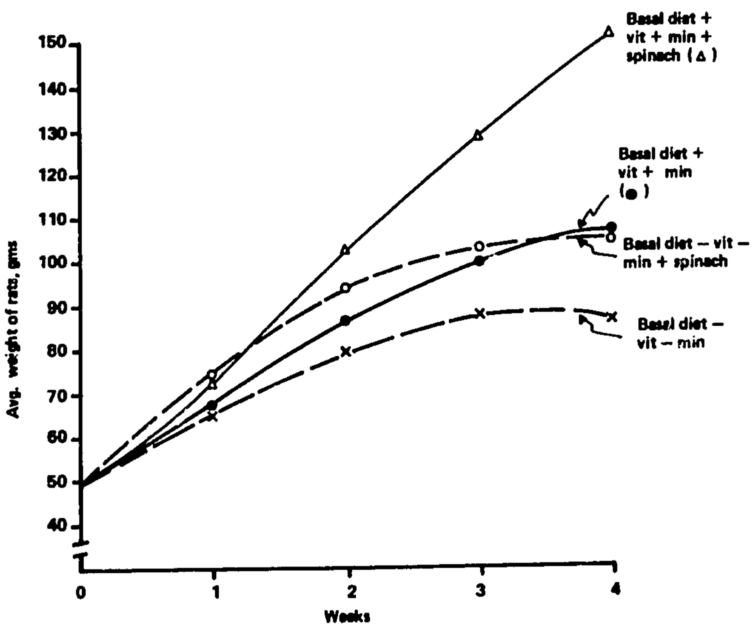

Figure 5. Effect of adding 5% spinach to a basal diet (90% maize/10% beans) with and without vitamin and mineral supplementation.

An additional experiment is shown in Table 12. In this case 87/13 and 70/30 maize/bean diets were supplemented with dehydrated Chinese peas. The test was conducted with basal diets with and without the addition of vitamin A. The results show that the dehydrated Chinese peas supplied the needed carotene for vitamin A production by the animal. This effect was more pronounced with the 87/13 maize/bean basal diet than with the higher quality 70/30 basal diet. The results would have been more convincing if the vitamin A analysis had been conducted in serum and liver. However, the results suggest that through the use of green vegetables it is possible to avoid vitamin A deficiency, one of the major nutritional deficiencies affecting world populations.

Table 12. Effect of supplementing maize/bean diets with Chinese peas with and without vitamin A supplementation.

Dietary treatment	Avg. final wt (g)	Avg. feed intake (g)	Feed effic.
Basal diet (A) + Vit. A + Chinese peas	147	429	4.20
Basal diet (A) - Vit. A + Chinese peas	156	432	3.89
Basal diet (B) + Vit. A + Chinese peas	163	468	3.96
Basal diet (B) - Vit. A + Chinese peas	153	422	3.91

Basal Diet A: 87% maize, 13% common beans.
Basal Diet B: 70% maize, 30% common beans.

Nutrition and health education for the mother is a fundamental long-range approach toward solving the problems of inadequate intake of vitamin A and increased requirements (32). Studies have shown that as little as 15-20 g of carotene leaves in a child's daily diet can maintain adequate blood levels to prevent xerophthalmia (25). Therefore, horticultural breeding programs should increase carotene concentrations as well as continue to improve yield performance. From the point of view of food product development, juices from high carotene leaves may prove useful in concentrating nutrients. Vegetables can also be useful in helping to reduce iron deficiencies, because of their high vitamin C content. For example, in a recent study (16,27) the inclusion of a fresh salad to a meal of hamburger, mashed potatoes, and green beans increased the absorption of nonheme iron from 0.36 to 0.66 mg. Not all of this effect is due to ascorbic acid, but it has a useful function. Thus ascorbic acid content should also be considered in vegetable breeding programs.

Green peas are another good supplementary protein food (Table 13). In this example, various cereal grains were supplemented with 20% green peas to simulate common dishes consumed in many parts of the world. A highly significant improvement in protein quality was observed in every case, with the poorest cereal grain, sorghum, giving the greatest response to the addition of green peas. These vegetables also contain carotene in relatively high amounts which should be increased, if possible, through breeding programs (4).

Table 13. Protein quality improvement of various cereal grains supplemented with green chickpeas.

	PER
Rice	1.30
Rice + 20% peas	2.50
Sorghum	0.45
Sorghum + 20% peas	2.03
Maize	0.93
Maize + 20% peas	1.44
Immature maize	1.03
Immature maize + 20% peas	1.86

Besides leafy vegetables and immature seeds such as green peas, potatoes are another vegetable food that can make significant contributions to improving poor quality diets. The protein quality of 12 potato varieties is presented in Table 14. The values,

Table 14. Relative protein quality of potato varieties.

Variety	Protein quality % of casein
Alpha	64.1
Loman	73.8
Anosta	68.1
Atzimba	72.1
Dias-71	57.7
Mara	52.4
Patrones	71.5
Procura	90.9
Tecpan-69	74.7
Toliman-69	68.9
Sta. Rosita	77.4
Utatlan-69	87.8

expressed as percentage of casein, show protein quality ranging from 52.4 to 90.9%. These results indicate that values are relatively high and that opportunities exist to produce and consume high protein potatoes.

The effect of beans on the performance of animals fed potato or yam flour as a base is shown in Table 15. Because amino acids were deficient in the food sources examined, the study was carried out with and without methionine supplementation. The results demonstrate some effect on growth when beans are added to potato flour. However, a significant improvement takes place with the addition of methionine. Growth performance with yam flour was not outstanding even when beans were supplemented with methionine (10).

Table 15. Effect of bean supplementation to potato flour and yam flour diets.

Level of beans in diet (%)	Avg. weight gain, g/28 days			
	- Methionine		+ Methionine	
	Potato	Yam	Potato	Yam
0	53.8	-14.5	-	-
10	70.8	-10.6	102.8	3.6
20	75.9	- 1.7	114.5	31.5
30	87.1	5.6	117.4	56.7
40	87.6	22.5	127.6	85.2

Conclusions

There are many options that can help reduce the problem of malnutrition. The problem is, of course, more serious for young growing children, particularly after weaning, as well as for pregnant and lactating women. The best solutions are offered by an intake of cereal and food legumes in such a proportion as to maximize their individual qualities. This insures good nutrition that can be further increased by the consumption of small amounts of animal products. Vegetables, however, can also play a role in supplementing cereal and legume diets.

Vegetables, particularly leaves, can supply significant protein if concentrated in dehydrated food products. An alternative to dehydrated products, leaf juices, could also be prepared. These preparations are precursors of the technology to produce leaf protein concentrates (26) and have been shown to improve the nutritional status of malnourished children (29,34). In addition to protein, however, juices can provide other nutrients present in the leaves. Flavor probably would be a problem, but not an insurmountable one.

Nutrition breeding programs for agricultural crops have emphasized cereals and food legumes. Vegetables, however, should receive equal attention and the non-conventional vegetables should also be considered. The literature on the impact of these food groups on improving the nutritional quality of diets is not readily available or abundant. However, the limited evidence available, the nutrient content of basic diets, and the nutritional deficiencies in the human population indicate that more attention should be given to the nutrients provided by vegetables. Of particular importance are vitamins A and C and some of the minor elements. Nutrition education programs should thus stress the consumption of these foods, especially by children, and simple home technologies should be devised to extract nutrients from vegetable leaves. The evidence demonstrates that through the appropriate use of available vegetable food products it is possible to attain good nutrition.

Literature Cited

1. The Asian Vegetable Research and Development Center. 1977. AVRDC Progress Report for 1976. Mungbeans. p. 61. Shanhua, Taiwan, R.O.C.

2. Bressani, R. and A. T. Valiente. 1962. All-vegetable protein mixtures for human feeding. VII. Protein complementation between polished rice and cooked black beans. J. Food Sci. 27:401-406.

3. Bressani, R. Complementary amino acid patterns. 1974. In: Nutrients in Processed Foods: Proteins. Eds. P. L. White and D. C. Fletcher. Publishing Sciences Group, Inc. Acton, Mass.

4. ______, L. G. Elias, and R. Gomez Brenes. 1977. Efecto suplementario del Gandul tierno o maduro al arroz, maiz tierno y maduro y al maicillo. Informe Anual INCAP.

5. ______. 1979. El sistema alimentario cereal-leguminosa de grano. Interciencia 4:254-259.

6. ______. 1982. Nutritional goals for plant breeders with particular reference to food legumes of the ICARDA programme. Presented at the Interfaces between Agriculture, Food Science and Human Nutrition in the Middle East, February 21-25, 1982, ICARDA/UNU, Aleppo, Syria.

7. ______, L. G. Elias, and J. E. Braham. The nutritional value of diets based on starchy foods and common beans. In preparation.

8. Derman, D. P., T. H. Bothwell, A. P. MacPhail, J. D. Torrance, W. R. Bezwoda, R. W. Charlton and F. G. H. Mayet. 1980. Importance of ascorbic acid in the absorption of iron from infant foods. Scand. J. Haematol. 25:193-201.

9. Elías, L. G., R. Gómez Brenes, and R. Bressani. 1978. Los potenciales de procesamiento y utilizacion de las hortalizas en la dieta humana. Informe Anual INCAP.

10. ______, S. Wayllace, M. Molina, and R. Bressani. Estudios sobre el valor nutritivo y utilización de la papa. 2. Evaluación de harina de papa producida por deshidratación de papa cocida. Arch. Latinoamer. Nutr. (Submitted for publication).

11. Erdman Jr., J. W. 1981. Bioavailability of trace minerals from cereals and legumes. Cereal Chem. 58:21-26.

12. Fritz, J. C., G. W. Pla, T. Roberts, J. W. Boehne, and E. L. Hove. 1970. Biological availability in animals of iron from common dietary sources. J. Agr. Food Chem. 18:647-651.

13. Gômez Brenes, R., L. G. Elías, and R. Bressani. 1979. Evaluación química de algunas verduras consumidas en Centro America. Informe Anual INCAP.

14. Goodard, M. S. and R. H. Matthews. 1979. Current knowledge of nutritive values of vegetables. Food Technol. 33:71-73.

15. Gopalan, C. and S. G. Srikantia. 1960. Leucine and pellagra. The Lancet 1:954-957.

16. Hallberg, L. and L. Rossander. 1982. Absorption of iron from Western type lunch and dinner meals. Amer. J. Clin. Nutr. 35:502-509.

17. Institute of Nutrition of Central America and Panama. 1969. Evaluación Nutricional de la Población de Centro América y Panama. INCAP Publication V-25. Guatemala.

18. ______. Division of Food and Agricultural Sciences. Unpublished data.

19. Jaggannathan, S. N. and V. N. Patwardhan. 1960. Dietary protein in vitamin A metabolism. I. Influence of level of dietary protein on the utilization of orally fed performed vitamin A and beta-carotene in the rat. Ind. J. Med. Res. 48:775-784.

20. Kelsay, J. L., W. M. Clark, B. J. Herbst, and E. S. Prather. 1981. Nutrient utilization by human subjects consuming fruits and vegetables as sources of fiber. J. Agr. Food Chem. 29:461-465.

21. Kies, C. 1981. Bioavailability. A factor in protein quality. J. Agr. Food Chem. 29:435-440.

22. Navarrete, D. A., O. M. Gutiérrez, and R. Bressani. Digestibilidad, valor proteínico y necesidades de proteína de dietas de plátano/frijol en jovenes adultos. Arch. Latinoamer. Nutr. In press.

23. Noor, M. I., R. Bressani, and L. G. Elías. 1981. The complementation effects on dietary protein of ungerminated and germinated mungbean (P. aureus) with rice. XII International Congress of Nutrition. San Diego, Cal. August 16-21.

24. Organizacion Mundial de la Salud. 1977. Salud Mundial. Las cinco enfermedades carenciales más importantes. Mayo:16.

25. Pereira, S. M. and A. Begum. 1976. Vitamin A deficiency in Indian children. World Rev. Nutr & Dietet. 24:192.

26. Pirie, N. W. (ed). 1971. Leaf Protein: Its Agronomy, Preparation, Quality and Use. IBP Handbook no. 20. Blackwell Scientific Publications, Oxford.

27. Rossander, L., L. Hallberg, and E. Bjorn-Rasmussen. 1979. Absorption of iron from breakfast meals. Amer. J. Clin. Nutr. 32:2484-2489.

28. Scrimshaw, N. S. and M. Béhar. 1961. Protein malnutrition in young children. Science 133:2039-2047.

29. Singh, N. 1968. Leaf protein in nutrition: Studies on production, nutritive value and utilization. Voeding 30:710.

30. Spencer, H., D. Osis, and C. L. Norris. 1978. Effect of a high protein (meat) intake on calcium metabolism in man. Amer. J. Clin. Nutr. 31:2167-2180.

31. Stoecker, B. and L. Arnrich. 1973. Patterns of protein feeding and the biosynthesis of vitamin A from carotene in rats. J. Nutr. 103:1112-1118.

32. Underwood, B. A. 1980. Strategies for the prevention of vitamin A deficiency. Food and Nutr. Bull. 2:11-14.

33. Vargas, E., R. Bressani, L. G. Elías, and J. E. Braham. 1983. Complementación y suplementación de mezclas vegetales a base de arroz y frijol. Accepted for publication in Arch. Latinoamer. Nutr.

34. Waterlow, J. C. 1962. The absorption and retention of nitrogen from leaf protein by infants recovering from malnutrition. British J. Nutr. 16:531.

35. World Health Organization. 1971. Food fortification protein-calorie malnutrition. Joint FAO/WHO Expert Committee on Nutrition. Eighth Report. Geneva, WHO. (Wld. Hlth. Org. Techn. Rep. Ser., No. 477).

36. ______. 1975. Control of nutritional anaemia with special reference to iron deficiency. Report of an IAEA/USAID/WHO Joint Meeting. Geneva, WHO. (Technical Report Series No. 580).

37. ______. 1976. Vitamin A deficiency and xerophthalmia. Report of a Joint WHO/USAID Meeting. Geneva, WHO. (Technical Report Series No. 590).