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RECENT DEVELOPMENTS IN THE PRODUCTION AND USE OF PROCESSED PROTEIN FOODS IN THE TREATMENT AND PREVENTION OF PROTEIN MALNUTRITION IN CHILDREN

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There is increasing recognition among nutrition workers that the diets consumed by the majority of low-income groups of the population in several tropical and sub-tropical countries are deficient in various important dietary essentials, such as proteins, minerals and vitamins.[1-4] Acute shortage of animal protein coupled with inadequate intakes of total protein are common in these countries (Table I). The consequences of consuming such deficient diets are strikingly seen in the vulnerable segments of the population viz., weaned infants, young children and expectant and nursing mothers. Protein malnutrition is widely prevalent among the children belonging to the low income groups of the population.[3,4] Protective and protein-rich foods such as milk, eggs, fish, meat etc., are not available in adequate quantities in the above mentioned countries.[3] The need for providing low-cost nutritious food supplements for overcoming the deficiencies in the diets has been stressed by several workers and also by international organizations like FAO, UNICEF and WHO.[5,6] Considerable amount of work has been carried out during recent years on the utilization of protein-rich foods of plant origin such as oilseed meals and legumes as supplements to human diets [7] The present review gives a brief account of the work relating to the development of processed protein foods of vegetable origin and of fish flour suitable for use as supplements to the poor diets and also for the treatment and prevention of protein malnutrition.

Table I. *Estimated calorie and protein content of national average food supplies (per capita/day)** (for the year 1961-62)

Region and country	Calories	Total Protein (g)	Animal Protein (g)
Europe :			
France	2990	99	53
Ireland	3440	91	55
United Kingdom	3250	88	54
North America			
Canada	3100	94	63
United States	3100	92	66
Far East :			
Ceylon	2050	44	8
India	2040	53	6
Pakistan	1970	45	17
Japan	2240	68	18
Africa and near East :			
Turkey	2830	91	16
Union of South Africa	2550	74	32
United Arab Republic	2530	75	12
Oceania :			
Australia	3150	90	59
New Zealand	3510	109	74
Latin America++			
Argentina	2930	83	50
Brazil	2710	67	18
Chile	2530	83	27
Mexico	2550	68	22

* FAO Production Year Book, Vol. 16, 1962
++ For the year 1960

Role of international organisations: Increased production and consumption of milk and other protective foods have been the keystone of the approach of international agencies, as well as many national and local groups in efforts to combat protein malnutrition in children. There is no doubt milk is by far the most effective supplement to the diets of children. However, it has become clear that the present production of milk in several tropical and sub-tropical countries is highly inadequate and there is little hope of increasing the

production of milk to the required level in the near future.[3] Many of UNICEF'S programmes of milk distribution are dependent on surplus dried skim milk from the United States. The present total world production of dried skim milk is of the order of 1.2 million tons, more than three fourths of this quantity being produced in U.S.A.[1] Even assuming that the entire world production of skim milk is made available (which is highly unlikely) at the rate of one ounce per child per day, the present production will be adequate only to supplement the diets of a small percentage of needy children. It is therefore obvious that other protein resources available in different regions will have to be utilised for preventing protein malnutrition among children. Consequently efforts have been directed by UNICEF and other national and international agencies towards the possible use of available sources of protein-rich vegetable foods and fish flour as supplements to the diets of children and in the treatment of protein malnutrition.[5,6]

International nutrition and health conferences held under the joint auspices of WHO, FAO and UNICEF have stressed the need for developing new sources of protein-rich foods for human feeding. The joint WHO-FAO-Macy Foundation Conference on human protein requirements held in Princeton in 1955 led to the setting up by WHO, of a Protein Advisory group to give guidance and encouragement to global programmes designed to develop new protein sources.[8] Projects reviewed by the WHO Protein Advisory Group have been in progress in several laboratories in Mexico, Gautemala, French West Africa, Nigeria, Belgian Congo, Uganda, Union of South Africa, India, Japan, United States, United Kingdom, Taiwan and Brazil. As a result of these investigations, considerable headway has been made in several countries in the utilization of oilseeds, oilseed meals, legumes and fish flour in feeding programmes[6].

Availability of protein-rich raw materials: In the processing of a protein food, due considerations have to be given to the availability of suitable protein-rich raw materials. These must be produced in the country on a large scale. They must also be available at low cost and be suitable for use as common food. Due consideration has also to be given to the nutritive value and consumer acceptability of the products.

The most important and abundant sources of proteins of vegetable origin available in different countries are the specially processed low-fat oilseed meals obtained from oilseeds and nuts such as soya bean, groundnut, sesame, cottonseed, sunflower seed and coconut and also pulses (legumes) such as grams, beans etc. Besides, marine fish is available in large quantities in certain countries and there is considerable scope for the production of fish flour.

Data regarding the production of certain oilseeds in some continents and in some selected countries in which protein malnutrition is widely prevalent is given in Table II.

Basic requirements of processed protein foods: In planning the production of processed protein foods for supplementing human diets, the WHO protein malnutrition Committee[9] suggested that it is necessary to take into consideration the following factors: (i) the amino acid content of the individual ingredients and the final product, (ii) the possible presence of toxic or interfering factors, (iii) the need for obtaining exact specifications for each of the components, (iv) the necessity of avoiding processes that damage the quality of protein, (v) the desirability of using products of local origin, (vi) the suitability of the product for feeding weaned infants and (vii) the acceptability of the product to the consumers. At the same time, the processed protein food should possess high nutritive value as tested by animal experiments and should have a significant supplementary value to the diets normally consumed by the people in the region. Although the primary objective is to provide a supplementary source of protein of good quality, it is desirable that a vegetable protein food should also contain adequate quantities of vitamins and minerals that are likely to be lacking in the diets of the low-income groups of the population.[6] This can be

Table II. *Production of major oilseeds and Bengal gram in India and some regions and selected countries of the world*+
(1000 metric tons per annum during 1961-62)

Region or country	Peanut (in shell)	Cotton seed	Sesame	Copra	Bengal gram	Soya bean
World Production (excluding USSR)	14,100	20,600	1500	3600	7600	31,000
North America	790	5,420	4	—	—	18,730
Latin America	—	2,800	205	255	140	310
Near East	230	1,940	225	—	145	5
Far East	5,990	2,540	530	2960	7010	1,290
Africa	3,900	460	140	110	140	30
India	4,757	1,600	501	254	6324	—
Indonesia	400	2	—	876	—	426
Mexico	90	766	115	180	118	—
Brazil	581*	1152	—	—	—	—
Nigeria	1245	56	12	3	—	15

+ FAO Production year book, Vol. 16, 1962
* Figures for the year 1960-61

achieved by fortification with certain essential minerals and synthetic vitamins which are at present being manufactured in large quantities at low-cost in U.S.A. and some other countries.

Possible sources of protein-rich foods: The following protein-rich foods have so far been utilized in the preparation of processed protein foods suitable for the prevention and treatment of protein malnutrition in children: (i) skim milk powder, (ii) oil seeds and nuts, (iii) oilseed meals, (iv) legume seeds, (v) protein isolates from oilseed meals and (vi) fish flour. The composition of the different processed protein foods developed both for the prevention and treatment of protein malnutrition is given in Table III.

Skim milk powder: The food which has been widely used both in the treatment and prevention of protein malnutrition in children by several workers is skim milk powder.[10,11] The world production of skim milk powder is of the order of 1.2 million tons, more than seventy five percent of this quantity being produced in the United State of America.[1] The countries in which protein malnutrition is widely prevalent, produce at present very little skim milk powder and have to depend mainly on imports.[1] It is highly desirable to encourage the production of skim milk powder in these countries. As discussed later, it is possible to stretch its availability by using it in admixture with other vegetable protein foods in the treatment of protein malnutrition.

Oilseeds and nuts: The most important edible oilseeds and nuts cultivated in different parts of the world are soya bean, peanut, sesame, cottonseed, coconut and sunflower seed [1] (Table II). Of these, soyabean forms an important crop in U. S. A., Indonesia, China and Japan, while peanut is cultivated in large quantities in India, China and Africa. Both soya bean and peanut are rich in proteins and fat and have been used in the preparation of milk substitutes and in the effective treatment of protein malnutrition, after suitable processing.

Studies carried out in China, India and U. S. A. have shown that milk substitutes prepared from soyabean and peanut form excellent supplements to the diets of children. Chick and Slack[12] and Dean[13] have shown that a highly nutritious spray dried food can be prepared from a blend of barley malt and soya bean. Dean[13] reported that about half the milk in the diet of infants upto one year age could be replaced by barley malt-soya mixture without affecting the growth and nutritional status of children. He also reported that there was hardly any difference in the growth of children receiving a supplement of barley malt-soya mixture containing 10% of dried skim milk. Shurpalekar *et al.*,[14] reported that a spray dried milk substitute from a 2:1 blend of soya bean and peanut

Table III. Chemical composition+ of Processed Protein Foods for treatment and prevention of protein malnutrition in children

Foods	Ref. No.	Protein (Nx6.25) (g)	Fat (g)	Carbo-hydrates (g)	Calcium (g)	Phosphorus (g)	Iron (mg)	Thiamine (mg)	Riboflavin (mg)	Nicotinic acid (mg)	Vitamin A (I.U.)	Vitamin D (I.U.)	Calories
1. Infant food based on soya-groundnut	16	24.7	18.6	51.5	1.05	1.13	7.2	0.85	1.23	8.2	2120	400	472
2. Indian Multipurpose food, formula-A	31	41.9	8.5	35.8	0.67	0.82	5.1	1.03	3.00	14.0	3000	300	387
3. Indian Multipurpose food, formula-C	31	40.6	7.0	39.0	0.80	0.86	4.2	1.11	2.80	10.4	2400	240	381
4. Protein food containing coconut meal	52	36.5	7.6	39.4	0.88	0.65	5.5	1.82	3.11	10.5	3000	300	382
5. INCAP-9B (*Incaparina*)	46	27.5	4.2	54.8	0.50	0.80	6.2	2.10	1.10	7.8	4500	—	370
6. Balanced Malt Food	30	31.9	4.9	43.0	0.58	0.55	6.7	1.50	3.00	8.5	3000	300	364
7. Nutro Biscuits	29	16.5	16.7	62.5	0.22	0.20	1.2	1.10	2.50	34.0	1520	700	466
8. Enriched tapioca macaroni	—	18.0	0.9	66.7	0.49	0.42	3.2	0.68	0.70	5.6	1500	100	347
9. Spray dried protein food based on groundnut protein isolate and skim milk powder	64	35.2	1.8	53.7	1.42	0.98	—	0.94	1.53	6.2	1500	400	372
10. Protein food based on a 4:1 blend of groundnut flour and skim milk powder	—	47.2	7.2	27.7	0.85	0.67	4.3	1.85	3.52	15.7	3000	300	334
11. Fish flour from oil sardine	83	84.2	0.12	—	3.77	2.26	—	2.40	3.65	16.5	5000	500	338
12. Protein food containing fish flour	83	51.6	5.3	25.3	1.80	1.51	—	1.51	2.10	9.9	3000	300	355

+ Values per 100g

possessed a high nutritive value, promoting satisfactory growth in albino rats. A spray dried milk substitute prepared from malt, soyabean and sesame is already being used in Indonesia as supplement to the diets of children.[15] In addition, there are other proprietary soya milk based spray dried infant foods, like soya-lac, Sobee and Mull-soy which are at present being commercially manufactured in America. The possibilities for the formulation of a complete infant food based on full-fat soya flour are being explored.[16] It is possible to manufacture such a product economically, since the processing will be less complex than that necessary for aqueous extraction and subsequent drying. Soya flour, optimally heat processed and fortified with dl-methionine and essential vitamins and minerals has been found to possess a nutritive value comparable to that of skim milk powder and hence the tremendous possibilities of soya flour in infant feeding.[17]

Fermented soya products like *Natto Miso* and *Tempeh* are quite popular in the far eastern countries and the possibility of using the same in the supplementary feeding programmes for the vulnerable groups of the population in the regions is receiving the attention of UNICEF and other international organizations. Extensive investigations carried out by Gyorgy[18] and Sano[19] have shown that the products are easily digestible and quite safe for human consumption.

It is obvious that there is considerable scope for the large scale production and utilisation of substitutes from soya flour as effective supplements to the diets of infants and children.

Soyabean and peanut have also been used for the treatment of protein malnutrition in children. Dean[20] successfully treated moderately severe cases of kwashiorkor using an emulsified mixture of well cooked soya bean and ripe banana fortified with vitamins. Thomson[21] tried the

same recipe of Dean[20] and reported satisfactory results in 23 out of 42 cases of protein malnutrition in children. More recently, Dean[22] reported that biscuit containing about 20% protein and made out of a blend of peanut kernel, 41 parts; skim milk powder, 15 parts; wheat flour, 6 parts; cotton seed oil, 6 parts; corn flour, 20 parts and sugar, 12 parts was highly effective in the treatment of protein malnutrition in children.

Oilseed meals

Considerable amount of work has been carried out in many countries during recent years in the utilisation of specially processed low-fat oilseed flours as supplements to the diet of children and also in the treatment of protein malnutrition in children. The world production of oilseed cakes has been estimated to be over 20 million tons. Even if half this quantity is suitably processed and fortified with vitamins and minerals, a considerable amount of fortified protein foods could be made available for use in protein malnutrition. Among the oilseed meals, the most important are, soya bean, peanut, cottonseed, sesame, sunflower and coconut.

Soya bean meal: The world production of soyabean is of the order of 31 million tons.[1] Processed low fat soya bean meals suitable for human consumption are being produced in large quantities in America for use as a supplement to human diets The value of toasted defatted soya grits and flour as dietary supplements has been established.

Borsook[23] developed a highly nutritious food by fortifying specially processed low-fat soya grits fortified with certain vitamins and minerals. Cooper and Bryan[23] reported that supplementation of the diet of school children with 1 oz daily of the above food for a period of five months produced a marked increase in the weight of the experimental subjects. Krishnamurty *et al.*,[24] have developed processed protein foods based on blends of soya bean, groundnut, sesame and Bengalgram of high nutritive value, as revealed by experiments on albino rats and showed the possibilities of using these foods as effective supplements to the diets of children. Sure[25] prepared a low-cost composite protein food containing soyabean.

Gomez *et al*,[26] treated successfully protein malnutrition in children with a soya preparation. They compared the progress of malnourished children treated with either a soya preparation or cow's milk and were unable to detect any difference in recovery by the clinical and biochemical criteria employed, except for a slower rise in total serum protein; the final serum protein levels in the two groups were, however, identical.

Peanut meal: The present world production of peanut is about 14 million tons per annum [1] Peanut is grown in large quantities in India, China. Africa and Indonesia. During recent years, considerable amount of work has been done in several countries on the utilization of low-fat peanut flour as a supplement to the diets of children.

Low-fat peanut flour has been used in the preparation of soup powder,[27] balanced food,[28] nutro biscuits,[29] low-cost malt food[30] and Indian Multipurpose food,[31] all of which have been shown to be effective supplements to the human dietary. Harris *et al.*,[27] developed a dehycrated soup powder containing peanut flour, soya flour, precooked pea flour and skim milk powder, together with added flavour and condiments and fortified with essential minerals and vitamins. Supplementation of the diet of school children with 1oz of soup powder daily brought about a considerable improvement in their nutritional status Lal and De[28] developed a balanced food in the form of broken vermicelli from a blend of peanut, soya bean, sesame, wheat and tapioca flours together with dried yeast, common salt and condiments. The product was found to be as nutritive as American Multipurpose food as assessed by feeding trials on children aged 4 to 10 years.

Subrahmanyan *et al.*,[31] standardized a method for the production of Indian Multipurpose food (Indian MPF), a dietary supplement made from a blend of 75 parts of specially processed peanut flour and 25 parts of Bengalgram flour fortified with vitamins and minerals. This product was found to be an effective supplement to the poor Indian diets as revealed by extensive

investigations on animals and feeding trials on children.[32-34]

Multipurpose food as such or in combination with 20 parts of skim milk powder has been reported to be highly effective in the treatment of kwashiorkor in children. Subrahmanyan *et al.*,[35] reported that Indian MPF with added skim milk powder when administered in daily doses of 4-5 oz in the form of a porridge was very effective in the treatment of kwashiorkor in children. Bharucha and Edibam[36] and Purushowthama Rao[37] successfully treated cases of kwashiorkor in children with Indian Multipurpose food. Multipurpose food is at present being produced on a large scale in South India and is being used as a supplement to the diet of school children.

Venkatachalam *et al.*,[38] treated successfully protein malnutrition in children with blends of peanut meal, sesame meal and Bengal gram flour. Serum albumin regeneration was, however, notably slower with these blends than with skim milk powder. When the treatment was sufficiently prolonged or the daily intake of protein increased, satisfactory levels of serum albumin were obtained with these blends. Hansen *et al.*,[39] found that a 2 : 1 blend of maize and cowpea meals was not effective in the treatment of protein malnutrition in children. They, however, observed that a blend containing equal parts of maize meal, maize germ and cowpea was effective in the treatment. But considering the small number of cases treated with the above mixture no definite conclusions can be arrived at. Senecal[40] reported that supplementation of the diets of children with incipient kwashiorkor with a 1 : 1 blend of millet and peanut flour with or without small amounts of added fish flour caused improvement in their growth and clinical symptoms. De Maeyer *et al* .,[41] as a result of investigations on the supplementation of a mixed diet with skim milk, or a combination of beans and peanuts, peanut flour or soya bean to children convalesing from kwashiorkor concluded that a combination of beans and peanuts produced a slightly better nitrogen retention in the children than a combination of soya bean and peanut flours. Both the blends, however, were inferior to skim milk powder in the above respect.

Cottonseed flour : The world production of cottonseed is about 21 million tons,[1] a good part of which is processed for the oil and cake. Among the different countries in which protein malnutrition is prevalent, cottonseed is grown in large quantities in India, Mexico and Brazil. Low-fat cottonseed flour obtained by expressing dehulled cottonseed kernels in a screw press followed by solvent extraction of the meal is rich in protein (40-45%) and can be used in the preparation of processed protein foods.

Cottonseed flour suffers from the defect that it contains gossypol which is toxic to animals.[42] Technological developments, however, have resulted in the production of cottonseed flour containing protein of high nutritive value and with low free and total gossypol content, which can be used safely for edible purposes. Raghunatha Rao *et al.*,[43] have standardized the conditions for the preparation of cottonseed flour by direct alcohol extraction of the kernels. The cottonseed flour so obtained was found to supplement poor vegetarian diets to a significant extent even when incorporated at 10% level.[44] Kass[45] has demonstrated the diverse ways in which edible cottonseed flour can be used for supplementing human diets. Scrimshaw[46] developed a vegetable mixture known as INCAP mixture 9 B containing specially prepared cottonseed flour, suitable for the treatment and prevention of protein malnutrition in children. The mixture contained corn, 29 parts; sorghum, 29 parts; cottonseed flour, 38 parts; dry torula yeats, 3 parts; calcium carbonate 1 part and vitamin A, 4500 I. U. This food was found to be very effective in the treatment of kwashiorkor in children. The product under the name of *Incaparina* is at present being produced on a large scale and distributed to the people in Guatemala.

Sesame meal: The present annual production of sesame is about 1.5 million tons.[1] Sesame is grown in larger quantities in India and to a lesser extent in Mexico. The use of sesame meal as protein source in human diets has been hindered to a considerable extent for want of equipment

for the large scale dehulling of the seed before crushing. The cake obtained from the seed without removal of the hull has excessive amounts of fibre and slight bitter taste and hence not suitable for use as such as a supplement to the diets of children.

Besides, it also contains large amounts of oxalate,[47] which may interfere in the utilisation of calcium Sesame seed can be effectively dehusked by soaking in water, followed by wet pounding. Dehusking of sesame can also be effectively carried out by lye treatment [48] Investigations carried out at the Southern Regional Research laboratories in U S A. resulted in development of an efficient and inexpensive process for the mechanical dehulling of sesame.[49] Dehulling of sesame results in the removal of husk which forms 10-12% of the seed and contains 80-90% of the calcium and oxalate present in the seed.[48]

Behar *et al.*,[50] have used whole sesame flour for the preparation of vegetable protein mixture for the treatment of protein malnutrition. INCAP vegetable mixture 8 developed by the above workers consisted of a blend of corn masa, 50 parts; sesame flour, 35 parts; cottonseed flour, 9 parts; torula yeast. 3 parts and kikuyu leaf. 3 parts The food was found to be quite effective in the treatment of kwashiorkor

Coconut meal: The world annual production of copra is of the order of 3 6 million tons [1] Cocount is grown in large quantities in Indonesia, India and Mexico Coconut meal obtained as a by product of the coconut oil industry contains about 20-25% proteins The presence of excessive amounts of fibre in the meal, however, precludes its use as a *sole* source of protein supplement in human diets [51] As such, coconut meal has found only limited use in human dietary.

Krishnamurthy *et al*.,[52] standardized the conditions for the preparation of a protein food from a blend of coconut meal (25 parts), peanut flour (50 parts) and Bengalgram flour (25 parts) fortified with vitamins and minerals Animal experiments and feeding trials on children have shown that this food has a significant supplementary value to poor Indian diets [53,54]

A process has been developed by Krauss-Maffei Company, West Germany for the integrated processing of coconut for oil and protein [55] Such a unit is at present functioning at the Central Food Technological Research Institute, Mysore. The aqueous phase, obtained by the centrifugal separation of oil from the emulsion (coconut milk) instead of being processed for the protein, can be concentrated as such to obtain coconut honey, rich in protein (28% on dry solids basis. Infant food and protein food formulations containing coconut honey, and possessing a high nutritive value have been prepared. The use of such products for the feeding of infants and weaned children will result in increasing three fold the available supplies of skim milk powder.

Sunflower seed meal: The world production of sunflower seed is about 1.6 million tons [1] Sunflower seed is grown mainly in Russia and Latin America (Argentina). Sunflower seed meal obtained by expressing the oil from kernels contains 45-50% of protein.

Sunflower seed has been used for the preparation of milk subsitutes suitable for infant feeding [56] In view of the high nutritive value of the proteins of sunflower seed, the use of the seed meal for the preparation of processed foods containing proteins of high biological value which can be used both for the supplementary feeding of children and also for the treatment of protein malnutrition in children appears to be promising.

Legumes: Legumes are important sources of proteins in human diets. Among the different legumes, Bengal gram *(Cicer arietinum)* and black bean are grown in very large quantities and have possibilities for use in the preparation of protein foods both for the prevention and treatment of protein malnutrition in children. The large scale use of legumes and legume flours is hindered to some extent because of tryptic inhibitors and some toxic factors present in most of them, which affect the nutritive value of the proteins [57] Optimum heat processing which helps to destroy trypsin and other inhibitors has been reported to significantly increase the nutritive value of several legumes proteins [58] The use of Bengal gram in the preparation of the Indian

Multipurpose food and its successful use in the treatment and prevention of protein malnutrition has been referred to earlier. Venkatachalam *et al.*,[59] have reported that Bengal gram *dhal* cooked under pressure and mixed with ripe banana and jaggery could be used for the treatment of kwashiorkor. Scrimshaw *et al.*,[60] reported that a processed protein food in which approximately half the protein was furnished by corn and the rest by beans was not effective in the treatment of protein malnutrition in children.

Protein isolate from edible oilseed meals: For effective treatment of protein malnutrition, large amounts of protein-rich foods of vegetable origin (about 120-250 g) providing about 58-60g of protein have to be administered.[59] In view of the severe anorexia and impaired digestion commonly observed in cases of kwashiorkor, it is generally difficult to administer such protein-rich foods in large quantities. On the other hand isolated oilseed proteins which are 2-4 times as rich in protein as oilseed meals and legumes may prove more suitable for the treatment of kwashiorkor than the parent materials. They can be administered along with readily assimilable carbohydrates like glucose, cane sugar and dextri-maltose. They possess a bland taste and are free from indigestible carbohydrates and odoriferous or bitter principles which are present in several legumes and oilseed meals. Only smaller quantities of the foods (about 70-80g) providing 50-60g of the protein need be administered to the children.

Subrahmanyan *et al.*,[61] successfully treated cases of protein malnutrition in children aged 1-5 years with three protein blends namely Blend I, a mixture of isolated peanut and soya bean proteins and casein fortified with dl-methionine and l-lysine, blend II, a mixture of 52 parts of peanut protein and 48 parts of skim milk powder and blend III a mixture of 66.6 parts of peanut protein and 33.3 parts of skim milk powder. The results indicate that a 2:1 blend of peanut protein isolate and skim milk powder can be used with considerable advantage in the treatment of kwashiorkor. An infant food formulation based on peanut protein isolate and full-fat soya flour was also found to be quite effective in the treatment of kwashiorkor. The photographs of a kwashiorkor child before and after treatment with the food are shown in Figs 1 & 2. Gopalan *et al.*,[62] have also reported that a blend of peanut protein isolate and skim milk powder is effective in the treatment of kwashiorkor.

The possibilities of using protein isolates for the preparation of foods suitable for the feeding of infants and weaned children has been shown by the recent investigations of Subrahmanyan *et al.*[63-65] The products reconstitute readily in water, yielding a milk-like emulsion and can easily be fed to infants and weaned children. The product not containing fat was also found to be quite effective in the treatment of protein malnutrition in children.[66]

Leaf and grass proteins : The amount of protein (lbs/acre/annum) that could be obtained from land varies with the crop[67]; as grass, 600; as beans, 370; as wheat, 269; as milk, 90 and as meat, 54. It has therefore been stated that it is highly economical to produce plant proteins, particularly leaf proteins for countries with large populations. The separation of the proteins from the fibrous material in leaves and grasses has long been a major problem in this field. Pioneering work in this field has come from Pirie and associates[68] and Slade and his coworkers.[69] According to the process developed by Pirie,[70] soluble proteins equivalent to 30-35% of the original nitrogen in the leaf is extracted, leaving the rest in the residue for use of farm animals. Extraction of the protein with solvents like acetone, removes the pigments and lipids and results in a palatable powder. The utilisation of isolated leaf proteins is beset with several problems such as the keeping quality, taste and acceptability of the product. Waterlow and Cruickshank[71] have successfully treated a few cases of kwashiorkor with mixtures of leaf protein isolate and milk. The results showed that the leaf protein-milk mixture was as effective as milk when providing the same protein content in initiating cure of kwashiorkor.

Fortification of plant proteins with synthetic amino acids : Another important appro-

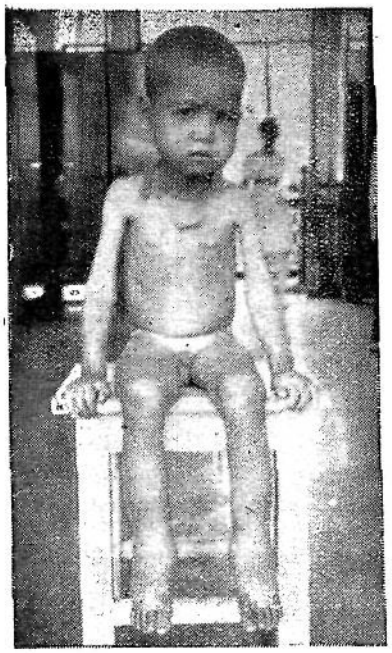


Fig. 1. Boy, three years of age with kwashiorkor, showing oedema of legs, hands and crazy pavement dermatosis



Fig. 2. Same boy after treatment with an infant food formulation based on peanut protein isolate and full-fat soya flour for thirty days

ach to the problem of meeting the protein requirements is by improving the biological value of low quality dietary proteins by supplementation with essential amino acids lacking in them. Most of the common vegetable proteins are deficient in lysine and/or methionine and fortification with the amino acids brings about a marked improvement in the protein efficiency ratio. Wheat proteins are improved by lysine, maize proteins by lysine, tryptophan and threonine and rice proteins by lysine and threonine.[72-74] Bressani *et al.*,[75] have shown that lysine supplementation caused a marked increase in nitrogen retention in children receiving 2 g protein/kg/day in the form of wheat flour. Truswell and Brock[76] have reported that lysine, tryptophan and isoleucine supplementation of maize diets supplying adults with 0.5-1.0g protein/kg/day resulted in a significant increase in the retention of nitrogen in all the subjects. Fortification of soya bean protein with methionine increased the PER of the protein to a level, nearly equal to that of milk proteins.[17] Fortification of peanut proteins with lysine, methionine and threonine, and sesame proteins with lysine has also been reported to effect a marked increase in the PER of the proteins.[77-78] It is evident from the above account that it is possible to improve considerably the nutritive value of vegetable proteins, by fortification with synthetic amino acids. In practical nutrition programmes, only fortification of dietary proteins with lysine and methionine can be resorted to, at the present time, since these two amino acids are being manufactured on a large scale at economic prices. The microbial production of different essential amino acids[79] holds great promise, and many of these amino acids may become available at low cost in the near future.

Fish flour: Edible fish flour, to which FAO has drawn the attention of nutrition workers and governmental authorities,[5] is a rich source of high class protein (70-80%) and essential minerals like calcium and vitamin B_{12} and as such will form an effective supplement to the diet of weaned infants, school children and expectant and

nursing mothers. A cheap fish flour seems to offer great advantages with regard to price, keeping quality etc., in comparison with canned fish or dried and salted fish products for the purpose of child feeding. Small quantities of the fish meal make large contributions to the provision of essential amino acids. A supplement of 15g of fish flour daily will meet all the amino acid deficiencies in the predominantly cereal diets consumed by children of the group 1-2 years, in several tropical and subtropical countries.

Considerable amount of work has been done on the preparation of and supplementary feeding with flavourless fish flour in Southern America and western Africa.[5] In Uganda, fish meals were tried as supplementary food for children and expectant and nursing mothers and was well accepted by all.[80] Fish flour was also introduced in the diet of patients recovering from kwashiorkor with very good results. Gomez *et al.*,[81] have successfully used fish meal in the treatment of kwashiorkor in children. Metta[82] reported that edible fish flour, even at as low levels as 1-3% had a significant supplementary value to the poor diets generally consumed in South East Asia. Shurpalekar *et al.*,[83-86] reported that edible fish flour obtained from oil sardine and a protein food based on a 2:1:1 blend of low-fat peanut flour, Bengal gram flour and fish flour had a significant supplementary value to poor Indian diets and was very effective in meeting the protein requirements of protein depleted rats. There is considerable scope for the large scale manufacture of edible fish flour from oil sardine and shark in India and its use as a supplement to diets of children in several states such as Bengal and Kerala.

Food yeast : The potentialities of yeast as a source of protein in the dietary, especially in the developing countries, have been generally recognized.[87] Yeast is capable of synthesising proteins from inorganic nitrogen in the shortest time. The efficiency of conversion of carbohydrate to protein by yeast is stated to be of the order of 16-33%. Yeast thus provides an excellent means of utilising industrial carbohydrates for producing protein. The practical use of food yeast in human diet dates back to first world war when Germany produced considerable quantities (nearly 20,000 tons per annum) of yeast chiefly from wood hydrolysates. The second world war revived interest in yeast as a source of dietary protein and the annual production in Germany went up to 100,000 tons. Food yeast is a pale yellow product with a nutty taste, and has been incorporated at 5-10% levels in processed protein foods intended for child feeding.[6] It has been estimated that three million tons of dried yeast will meet the protein requirements of 1000 million needy children. There is considerable scope for the use of food yeast as an ingredient of low-cost protein foods intended for overcoming protein malnutrition in children.

Algae : Much has been written recently about algal culture, particularly regarding the production of unicelluar green algae, *chlorella*.[88] When cultured under optimum conditions, *chlorella* attains a protein content of about 50-60%. The proteins of *chlorella* are good sources of all the essential amino acids, except methionine and cystine. The protein efficiency ratio of the proteins of *chlorella* has been reported to be of the same order as that of yeast and peanut protein.[89] Studies carried out in Japan have shown that considerable amounts of dried *chlorella* can be added to green tea, soups, noodles and baked products without affecting their taste and appearance.[90]. Feeding trials carried out on humans[91] have shown that consumption of 100g of powdered algae daily was well tolerated. Consumption of larger amounts resulted in nausea, vomiting, abdominal distension, flatulence and bulky hard stools. No other evidence of toxicity was found and the other gastro-intestinal symptoms disappeared shortly after the consumption of algea was discontinued. The results have shown that further work is necessary to improve both the acceptability and digestibility of processed algae before it can be recommended for supplementary feeding.

An extrapolation of pilot plant results indicate that an annual yield of 17.5 tons of *chlorella* per acre is possible with the present technological knowledge.[92]

Marine algae is another important source of human foods.[93]

Production and utilization of protein supplements in India : In view of the widespread occurrence of protein deficiency among weaned infants and pre-school children and other vulnerable sections of the population and scarcity of protein-rich foods in the country, there is an urgent need for the large scale production and distribution of protein-rich foods.

Data regarding the quantities of different oilseed meals available in the country as well as the quantity of protein contributed by them are given in Table IV.

Table IV. *Oilseeds and oilseed meals as sources of protein in India*+

Commodity	Annual production (1000 metric tons)	Yield of meal (1000 metric tons)	Average protein content of meal (%)	Available protein (1000 metric tons)
Peanut (kernels)	3330	1984	50.0	992.0
Cottonseed	1600	768	47.0	361.0
Sesame seed	501	250	33.3	83.3
Copra	254	127	21.0	26.7

+ FAO production year book, Vol. 16, 1962

The total available protein amounts to 1.5 million tons. On the assumption that about 10g of additional protein per day will be required to make up the protein deficiency in the average diets of children and expectant and nursing mothers and that 50% of the available supply of oilseed meals are available for human consumption, the protein deficiency in the diets of 180 million needy individuals can be met.

Mainly due to the extensive work carried out at the Central Food Technological Research Institute, Mysore, the scope of peanut flour as a protein source for some countries has been recognised by international agencies and this has resulted in the UNICEF help for the setting up of two plants, each with a capacity of 10 tons/day for the production of edible peanut flour in the country. Both the plants have been erected and are expected to go into production shortly. The peanut flour produced will be used for the production of larger quantities of processed protein foods which can be used as effective supplements to the poor dietary of the people. The need for the large scale production and distribution of processed protein foods in developing countries for eradicating protein malnutrition was stressed in the first FAO/UNICEF meeting with the food industries on protein-rich foods held in Rome during 21-25 October 1963.[94] The meeting also discussed problems connected with the production and marketing of protein-rich foods such as processing, quality characteristics and control, packaging, acceptability testing and economic and marketing feasibility.

Apart from the work relating to production, laboratory and clinical evaluation, considerable amount of extension work has been carried out by the extension wing of this institute for popularising the use of protein supplements. Since October 1957, our Institute has produced 500-600 tons of Indian Multipurpose Food, and this has been distributed widely throughout India by various agencies including the American Meals for Millions Foundation, for feeding trials in schools, hospitals etc. The Indian Multipurpose Food is now recognised as a nutritious and acceptable protein supplement. A factory with a capacity of 4-5 tons of Indian MPF was set up in 1960 in Coimbatore, South India by a private industry with the technical help of this Institute. The entire production of Multipurpose Food from the plant is being purchased by the Madras Government for use in the mid-day meal programme in schools. The Ministry of Food and Agriculture, Government of India has plans to set up units for the manufacture of Multipurpose Food at different important centres in India, for use in mid-day school feeding programmes. It is to be hoped that large scale production and distribution of processed protein foods will be undertaken throughout the country in the near future for eradicating protein malnutrition.

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