C H A P T E R I

INTRODUCTION

CHAPTER I

INTRODUCTION

Malnutrition, in its various forms, is one of the world's most pressing health problems - a problem made more and more critical by the increased rate of population growth. Malnutrition results in nutritional deficiencies which lead to high death rates, disabling diseases, stunted physical stature, poor work performance and greater susceptibility to infections and accidents (Berg, 1968).

Food supply below the level of nutritional requirements is the main problem facing the developing countries. Relatively few countries such as the U.S.A., Canada and Western European countries have an abundant and varied food supply. According to FAO (1963), the per capita availability of proteins and calories in different countries is as shown below :

Country	Calories	Total protein (g)	Animal protein (g)
U.S.A.	3090	91	65
Mexico	2680	75	24
Brazil	2290	65	18
Pakistan	1980	44	7
India	2000	51	6
Philippines	1800	42	14
Japan	2290	70	21

The figures for available calories do not indicate the adequacy of food supply because food balance tables are averages and even in countries with adequate food supplies malnutrition occurs extensively among the poor classes (Hand, 1966; Beaton, 1967). Further, the distribution of food even within the same family may be far from equitable. For instance, in an otherwise adequately nourished family, young children may not get enough to eat because of the unsuitable nature of the meals prepared in the adult-oriented home. In this country addition of spices to legumes and vegetables makes them unsuitable for young children (Patwardhan, 1962). Similarly, people with teeth troubles or the convalescent may not be able to find the meals normally prepared suitable. Food-sharing practices may also operate against the equitable sharing of protective foods. The head of the house is served first and given favoured treatment whereas women in the reproductive period eat last resulting in an unequal sharing of protective foods.

The situation in India is critical because of the enormous increase in population without a parallel increase in the production of foods. The population of India was 361 millions in 1951, 443 millions in 1961 and has already risen to 476 million by the beginning of 1965 (Directorate of Economics and Statistics, 1965). The rate of increase in population per year is 2.2% whereas the food production

(1958-64) is increasing at the slow rate of 0.6% per year, prior to 1965 (Directorate of Economics and Statistics, 1965) not taking into account the drought situations prevalent for the last two years.

Apart from the quantitative lack, the diet consumed is also poor qualitatively as the diet of the poor is heavily based on cereals with not enough of milk or animal foods or legumes. Similarly, the lack of eggs and dairy products providing vitamin A is not compensated by an adequate consumption of vegetables and fruits which can provide carotene. The diet of children in the postweaning period is even more inadequate because of the unsuitable nature of the foods prepared.

Many programmes are being carried out at present for preventing malnutrition and undernutrition in the pre-school child by various international agencies such as UNICEF and FAO (Autret, 1964; Pate, 1964; Harman, 1966; Teply, 1966). Such programmes generally aim at nutrition education as well as more efficient food production. However, the number of centres which carry out such programmes is at present limited.

Efforts have been made to popularise processed food mixtures with a high protein content, but they have hardly made an impact even in urban areas and are totally unknown in rural areas. This is due to several reasons. Processing

inevitably increases the cost of foods usually by at least 100%. In this country, the average amount of money spent on food is of the order of eighty paise (1 U.S. cent = 8 paise) per day in urban areas and sixty five paise in rural areas (Sukhatame, 1965) and the supplies available for this amount are hardly adequate even when the money is used for the purchase of raw foods. The villager can hardly be expected to allow his supplies to dwindle further by the use of processed foods.

Secondly, the use of centrally manufactured foods poses problems in transportation and distribution. When we consider the difficulties involved in distributing even a part of the food grains consumed, the magnitude of the problem can be easily visualized. The acceptance of processed foods is yet another problem as pointed out by Gyorgy (1966).

Any attempt at improving the nutritional status of the poor man must therefore aim at enabling him to make a more efficient use of locally available sources of foods. He must be educated on the relation between nutrition and physical stature, mental characteristics such as cheerfulness and alertness, efficiency of work performance, health, and susceptibility to infection etc. Any advice given to him must be based on what he produces already or can easily produce, and be consistent with his economic capacity.

The availability of land and the cost of foods are therefore crucial considerations. The food preparations suggestdd should be appropriate for the kind of kitchen equipment available in rural homes. The advice given must be based on suitable modifications of the existing diet rather than novel foods unknown to the villagers. For instance, soya bean and its milk may be excellent foods, but in this country, it will be easier to educate the farmer in the use of pulses which are commonly cultivated.

It is evident that, in order to give the right kind of advice, we have first to identify the existing dietary patterns and their inadequacies and consider how they can be improved with locally available resources.

Extensive diet surveys have been carried out in India during the past two decades (ICMR Report 20, 1951; Lal,1952a 1952b; Mitra, 1953; Govil, Mitra and Pant, 1953; Radhakrishnarao, 1956; Belavady, Pasricha, and Shankar, 1959; Pasricha, 1959; Jyothi, Dakshayani, Swaminathan and Venkatachalam 1963; Rajalakshmi and Nanavaty, 1964; Saha and Seal, 1965). These surveys have shown that the diets are composed primarily of cereals with poor consumption of pulses, leafy vegetables and negligible consumption of animal foods such as eggs, milk and meat. They have generally pointed to a deficiency of calories, protein, vitamin A, and B vitamins particularly with regard to

riboflavin in all areas, and thiamine in areas consuming polished rice. However, these surveys have been mostly carried out on families using the oral questionnaire method. As pointed out earlier, the information derived may not reflect the intake of particular groups such as children in the post-weaning period.

Very few quantitative reports on the dietary intake of particular age groups are available except perhaps in the case of expectant and nursing mothers. However, extensive observations have been made on the feeding practices of young children (Jelliffe, 1955; Rao, Swaminathan, Swarup and Patwardhan, 1959; Mukherjee, 1959; Krupadanam, 1960; Anand and Rao, 1962). Prolonged breast feeding up to the age of 2 years or more is a common practice. Supplementary foods are not deliberately introduced and the child has usually to help himself to as much of the adult foods as he can get or consume. However, breast feeding is often terminated earlier if pregnancy occurs within the nursing period. In regions such as Gujarat, where not much rice is used, the unsuitable nature of available foods such as hard rotis and highly spiced dals results in calorie deficiency and marasmus. In regions such as Kerala, Madras and Bengal, the child is given a diet consisting of softly cooked rice, tapioca or sago resulting in a high incidence of kwashiorkor (Jelliffe, 1955; Rao, Swaminathan, Swarup and Patwardhan, 1959 .

Such high carbohydrate diets also precipitate vitamin A deficiency in young children (Gopalan, Venkatachalam and Belavady, 1960).

Some of the available data on the nutrient intake of pre-school children in this country are presented in Table 1. The data show the inadequacy of the diets with regard to calories, protein, vitamin A and calcium. In some of the studies less than 60 calories are available per kg. of body weight as against 90 - 100 recommended (ICMR, 1944; Hansen, 1959) although the children have low body weights. Similarly, common diets consumed by children contain less than 20 g protein per day. Calcium intakes are nowhere near the amounts recommended by FAO/WHO (1962). Vitamin A intakes are poor even when considered on the basis of body weight as about 70 I.U. per kg. of body weight seem desirable during this age (FAO, 1967). The requirement will be much more when the vitamin has to be derived from carotene.

During the past few years there has been a growing awareness of the relation between dietary intake and growth of children. Considerable evidence is now available on the effects of malnutrition on physical growth. Weight, height and growth measurements of children carried out in many areas of the world where dietary deficiencies exist indicate the effects of diet on body build. Weights and heights of children belonging to different parts of India

Table 1. Dietary intake of pre-school children of the poor class reported from India

Author	Region	Calories	Protein (g)	Calcium (mg)	Vitamin A (I.U.)
Bansal *et al* (1964)	Hyderabad	565	13	130	-
Dumm (1966)	Vellore	581	15	-	-
Rao *et al* (1959)	South India	610	15	-	-
Pasricha (1959)	Hyderabad	690	14	-	-
Venkatachalam *et al* (1954)	Coonoor	736	16	70	120
Subrahmanyan *et al* (1959)	Mysore	766	17	374	930
Belavady *et al* (1959)	Nilagiri	781	16	221	-
Rao and Rao (1958)	Vellore	799	21	236	378
NRL - Report 66-67 (1968)	Andhra Pradesh	820	19	-	-
Gopalan *et al* (1960)	Hyderabad	-	-	-	450

and reported in the literature are presented in Tables 2 and 3. The values reported for the low socio-economic group children are considerably lower than the few values available for upper socio-economic group children. This is obviously due to the fact that body weights of the poor group remain more or less stationary during the post-weaning period. Available reports suggest that the birth-weight and growth-rate of poor infants are not appreciably different from those of upper class children (Patwardhan, 1956; Gopalan, 1958). After the first six months of life, the growth rate tends to fall off in the poor infants compared to those of the upper class. Data obtained in longitudinal studies carried out in Baroda on the growth rate of infants in low and high income groups are presented in Figure 1.

The effect of growth retardation during childhood may be a permanent stunting evident in the adult stature attained. Thus, although birth weight does not differ much in the lower and upper class, adult heights and weights are found to differ significantly (Rajalakshmi and Chandrasekharan, 1967).

An inadequate diet not only affects growth and physical stature because of the quantitative inadequacy of the diet but also results in specific clinical symptoms because of particular deficiencies.

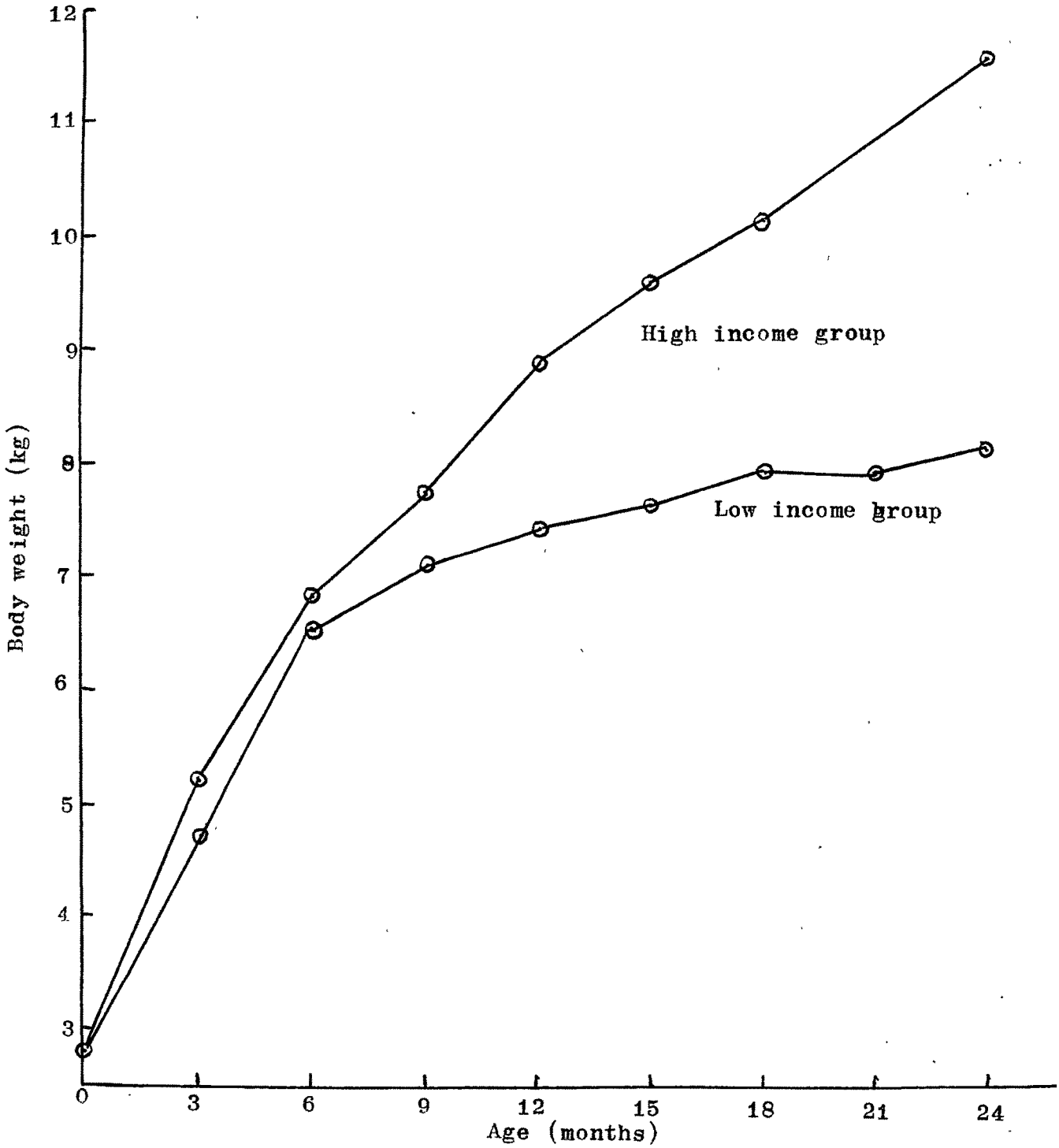
Table 2. Data on weights (kg) of pre-school children in India

Authors	Region	Body weight (kg)				
		Age (years)				
		1 to 2	2 to 3	3 to 4	4 to 5	5 to 6
Subjects for low income group						
Homawalla	(1958) Andhra Valley	7.1	8.0	9.3	11.4	-
Rao et al	(1959) South India	8.0	9.7	11.3	12.5	-
Rajalakshmi and Chandrasekharan	(1967) Baroda	7.7	8.6	10.4	11.8	13.2
Rao et al	(1954) Nilagiri	7.6	10.0	11.5	13.0	-
Phadke	(1957) Poona	-	-	10.3	12.0	12.7
Currimbhoy	(1963a) Bombay	7.7	9.6	11.2	12.6	14.2
Datta et al	(1963) Pondicherry	8.1	11.1	-	12.5	13.1
Chaudhari et al	(1964) Calcutta	7.7	9.8	10.8	13.1	14.6
Udani	(1963) Bombay	9.0	10.8	11.2	12.4	14.0
Subjects for middle and high income groups						
Athavale	(1959) Bombay	-	-	13.5	14.1	15.7
Rajalakshmi and Chandrasekharan	(1967) Baroda	9.1	11.4	13.2	14.5	15.9
Currimbhoy	(1963a) Bombay	10.9	14.4	15.2	16.8	18.0
Udani	(1963) Bombay	12.3	14.5	16.3	18.6	19.2

Table 3. Data on height (cm) of pre-school children in India

Authors		Region	Height (cm)				
			Age (years)				
			1 to 2	2 to 3	3 to 4	4 to 5	5 to 6
Subjects for low income groups							
Homawalla	(1958)	Andhra Valley	67.8	76.4	84.2	90.0	-
Rao et al	(1959)	South India	75.1	81.4	89.0	95.1	-
Rajalakshmi and Chandrasekharan	(1967)	Baroda	68.6	73.7	83.8	91.4	96.5
Rao et al	(1954)	Nilagiri	-	74.4	82.6	89.5	95.4
Phadke	(1957)	Poona	-	-	82.2	89.5	108.5
Currimbhoy	(1963a)	Bombay	72.3	80.5	86.8	94.9	99.3
Datta et al	(1963)	Pondicherry	75.3	86.5	-	92.3	99.4
Chaudhari et al	(1964)	Calcutta	77.1	80.2	90.8	98.4	103.7
Udani	(1963)	Bombay	75.9	82.2	84.7	88.5	101.2
Subjects for middle and high income groups							
Athavale	(1959)	Bombay	-	-	92.6	98.4	105.8
Rajalakshmi and Chandrasekharan	(1967)	Baroda	73.7	83.8	94.0	101.6	106.7
Currimbhoy	(1963a)	Bombay	80.7	91.0	97.4	106.3	111.6
Udani	(1963)	Bombay	84.2	92.1	102.7	108.8	115.7

Fig. 1. Body weight (kg) of infants in low and high income groups*.



* Rajalakshmi, R. and Subbulakshmi, G., unpublished)

For the past 30 years a large number of surveys have been carried out on the clinical status of subjects in different parts of India. However, such surveys have largely been carried out on children of the school going age with relative neglect of the other vulnerable groups, particularly pre-school children (Gopalan and Rao, 1961). Occurrence of xeropthalmia, Bitot's spots, night blindness, angular stromatitis, angular conjunctivitis, glossitis, phrymoderma, bleeding gums, folliculosis and rickets are reported to the extent of up to 15% in pre-school children belonging to the low socio-economic groups (Gopalan and Rao, 1961; Patwardhan and Jagannathan, 1962) not to mention kwashiorkor and marasmus which will be discussed later.

Occular manifestations are the most common signs observed in several of the nutrition surveys conducted in India (Gopalan and Rao, 1961). They include a variety of conditions such as diffuse or patchy pigmentation, xerosis, Bitot's spots, keratomalacia, corneal vascularisation, lachrymation etc. Although Bitot's spots cannot always be attributed to vitamin A deficiency (McLaren, 1960) it seems to be the most common cause on the basis of dietary intake, serum level and response to treatment of subjects manifesting the symptom (Bagchi, Halder and Chowdhury, 1959; Pereira, Begum and Dumm, 1966). The deficiency of vitamin A in the sort of high carbohydrate diets that result

in kwashiorkor is aggrevated by poor absorption and utilization of the vitamin because of protein deficiency. About 1% of the population in this country is blind because of a combination of vitamin A deficiency and infections. Much of this occurs before the age of 2-3 years in areas where kwashiorkor is widely prevalent (Gopalan and Ramalingaswami, 1955). If not for the high mortality rate during the preschool years, we might have a higher incidence of blindness.

Next to occular manifestations, skin changes like hyperkeratosis, folliculosis or phynoderma are widely reported in India; many of the studies suggest that the skin changes cannot be completely attributed solely to vitamin A deficiency, but may also be due to other factors including a deficiency of essential fatty acids and fats. (Rajagopal and Chowdhury, 1952; Bagchi, Halder and Chowdhury, 1959; Patwardhan, 1961). Infantile eczema, so common in children brought up on starchy gruel in South India might be a result of poor intake of essential fatty acids.

Alimentary manifestations such as angular stromatitis, cheilosis, glossitis and bleeding gums are frequently found. The nutritional significance of some of these signs are not too clear. However, many of these signs are associated with a deficiency of the B complex groups of vitamins, particularly riboflavin (Jolliffe, 1960).

In addition, there is a localised incidence of nutritional diseases such as beriberi which is prevalent in areas such as Andhra consuming highly polished rice. Pellagra has been occasionally reported in people consuming rice (Raman, 1933), maize (Bajaj, 1939) and jowar (Gopalan and Srikantia, 1960). Goitre is a major public health problem in the Himalayan regions (Ramalingaswami, Subramanian and Deo, 1961). Fluorosis is found to occur in certain areas where water has a high fluorine content (Pandit, Raghawachari and Rao, 1940; Venkiteswaralu, Narayanarao and Ranganatharao, 1952). Frank scurvy has rarely been reported although common diets are not rich in vitamin C but subclinical forms of the same are suspected (Chakravarthy, Sur and Kandelwal, 1958; Manchanda and Gupta, 1959; Kurup, Ghai and Taneja, 1961).

About one to three percent of children in the age group of one to five would appear to suffer from rickets. Hospital records of cities such as Bombay and Calcutta indicate a fairly good number of ricket cases (Currimbhoy, 1963a; Chaudhuri, 1961). The low calcium content of the diet and the fact that most of it is derived from poorly utilized sources combined with a deficiency of protein would lead us to expect a higher incidence of rickets. It is possible that the effects of calcium deficiency are not as evident

as they might otherwise be when calories and protein are the limiting factors in the diet.

Assessment of nutritional status by clinical examination suffers from certain limitations as sublinical deficiencies cannot be detected by such examination. With the development and refinement of biochemical techniques and greater knowledge about the biochemical parameters affected by malnutrition, biochemical criteria are increasingly used in the assessment of nutritional status. (Arroyave, 1962; Pearson, 1962a, 1962b; ICNND, 1963; Krehl, 1964). However, in this country hemoglobin and serum proteins are the most commonly used parameters and extensive data are not available on other parameters such as serum vitamin A and carotene, serum ascorbic acid, and urinary excretion levels of creatinine, thiamine, riboflavin, nitrogen etc. especially in the case of pre-school children.

The available figures for blood hemoglobin and serum proteins are presented in Tables 4 and 5. In most of the studies carried out on children who are apparently illnourished low values of both are found, whereas a low hemoglobin content may be due to vitamin-mineral or protein deficiency or the prevalence of intestinal parasites, protein deficiency is the primary cause of low serum protein levels except when protein synthesis is affected because of chronic illness or infections or liver damage. The poor protein status of the

Table 4. Hemoglobin (g/100 ml blood) values reported for pre-school children in India.

Author		Hemoglobin (g per 100 ml)
Swaminathan et al	(1960)	7.8
Currimbhoy	(1963b)	8.1
Pereira and Baker	(1966)	8.5
Venkatachalam et al	(1954)	9.3
Datta et al	(1963)	9.9
Subrahmanyan et al	(1959)	10.0
Rao et al	(1959)	10.5
Rao	(1960)	10.6
Chaudhuri et al	(1964)	11.3
Doraiswamy et al	(1964)	11.4
Pereira and Baker	(1966)	11.5
Rao et al	(1954)	12.2
Patel et al	(1957)	13.3
Nutrition survey U.P.	(1952)	13.3
Haideri et al	(1961)	13.5

Table 5. Values for albumin and protein content of serum reported in preschool children.

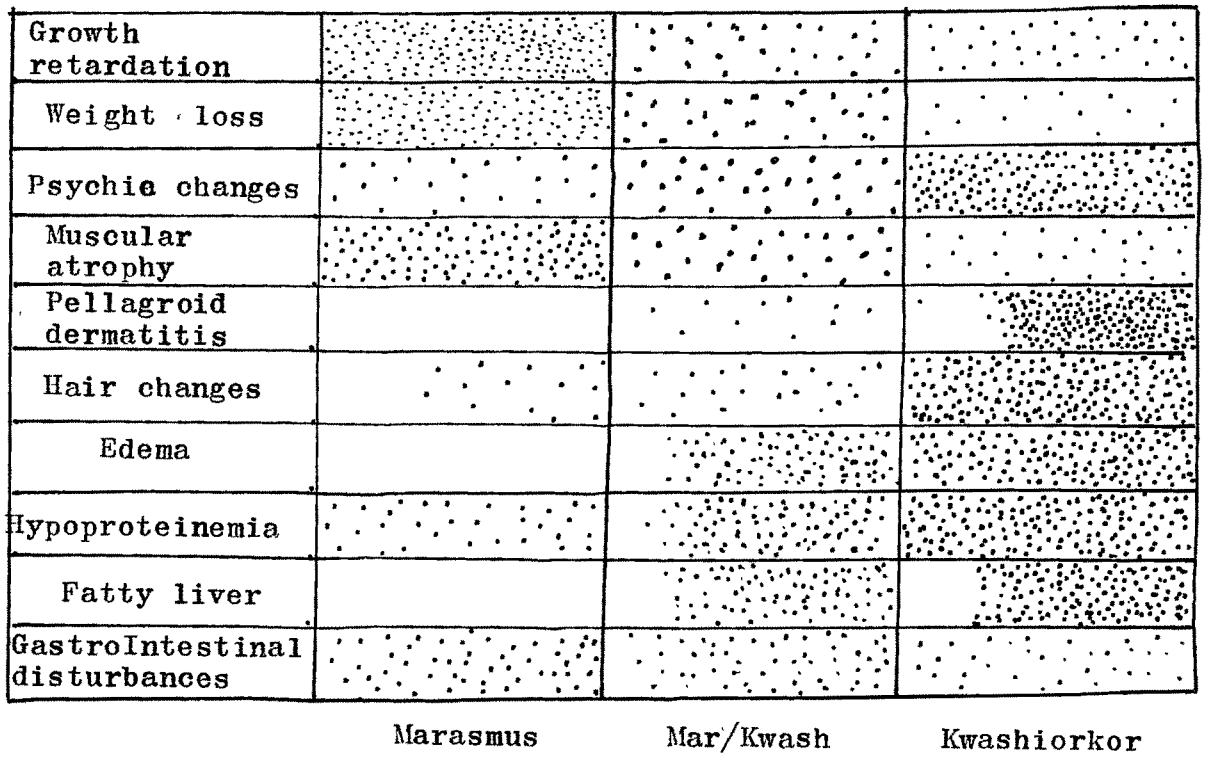
Authors		Amount (g) per 100 ml of serum	
		Total protein	Albumin
Studies including both malnourished and apparently healthy subjects			
Jayalakshmi and Mukundan	(1961)	4.8	1.4
Bhagwan et al	(1962)	3.9	1.7
Kulkarni et al	(1960)	4.5	1.8
Patel et al	(1958)	4.5	1.9
Venkatachalam et al	(1954)	4.5	2.1
Haideri et al	(1961)	4.7	2.2
Ramanathan	(1955)	4.3	2.4
Chaudhuri et al	(1964)	5.6	3.2
Rao et al	(1959)	6.5	3.4
Studies in apparently healthy subjects			
Pereira and Baker	(1966)	7.0	3.6
Samadi	(1966)	6.3	3.6
Dumm et al	(1966)	6.5	3.7
Udani and Panwalkar	(1963)	6.6	3.8
Kulkarni et al	(1960)	6.5	4.0
Haideri et al	(1961)	6.9	4.4

children is evident from the low serum protein levels. The high incidence of kwashiorkor and marasmus single out protein - calorie deficiency as the most crucial one in pre-school children.

The collective symptoms of chronic undernutrition and malnutrition in children was first described by Williams (1933) who used the term of 'kwashiorkor' or 'displaced child syndrome' to indicate a collective symptom associated with severe protein deficiency in the post weaning period. The disease was so called because of its frequent association with the onset of pregnancy or arrival of a younger child, resulting in the sudden cessation of breast feeding, and possibly, also decreased psychological attention from the mother, with the simultaneous switching over to highly starchy foods. Another form of malnutrition caused by a restricted supply of both protein and calories came to be labelled as marasmus. More recently, the term protein-calorie malnutrition has come in use (Jelliffe, 1959). This term sums up the relationship of dietary calories and protein to the development of the disease and covers kwashiorkor, marasmus and marasmic kwashiorkor. The differential clinical signs associated with these are shown in figure 2.

Kwashiorkor is common in all tropical and subtropical underdeveloped regions of the world (Brock and Autret, 1952;

Fig. 2. A schematic presentation of the variation of intensity of* signs and symptoms in Kwashiorkor and marasmus.



* Behar, M., Viteri, F., Bressani, R., Arroyave, G., Squibb, R.L. and Scrimshaw, N.S. (1958).

Trowell and Davies, 1952; Jelliffe, 1955; Rao et al, 1959). A large number of cases are also reported in India (Hare, 1947; Ramalingaswami, Menon and Venkatachalam, 1948; Achar, 1950; Achar and Benjamin, 1953; Gopalan and Ramalingaswami, 1955; Chaudhury, 1961; Webb, John, Begum, Pereira and Dumm, 1964). It is to be noted that all these reports are from rice-consuming regions. It may be assumed that for every frank case of kwashiorkor admitted in hospitals, there may be four cases remaining unnoticed and many more cases in a state of marginal malnutrition (WHO, 1963).

Clinical symptoms seen in kwashiorkor children are loss of appetite, dullness, peevishness and irritability (Trowell and Davies, 1952; Brock and Hansen, 1962). Associated symptoms are occasional brownish discolouration of the hair (Platt and Nagchaudhari, 1954) and peeling skin. Growth failure and edema are found in most cases, often in association with vitamin deficiency symptoms. The extent of growth failure depends upon the severity of the disease.

Children suffering from protein malnutrition not only have poor protein stores and poor lean body mass, but also suffer from a poor development of bone growth (Jones and Dean, 1956). This is partly because the sort of diets which result in kwashiorkor are also deficient in calcium, and also because the absorption and utilization of calcium are

impaired with a low protein diet on the basis of animal studies (EL-Maraghi, Platt, Stewart, 1965). According to Garn (1966) even in the case of children rehabilitated with a good diet it may take more than one year to achieve normal ossification status.

The loss of tissue in kwashiorkor is often masked by edema for which hormonal as well as physico chemical mechanisms have been suggested. According to Jolliffe (1962) the osmotic pressure of serum proteins, especially that of albumin, is one of the factors involved. Edema, present in most cases of kwashiorkor, is found to subside within 10 to 30 days after high protein therapy.

Hypoproteinemia is a constant feature of kwashiorkor cases which seems to be primarly due to a decreased albumin level (Allison, 1955). The same is believed to be due to decreased synthesis rather than increased catabolism (Gitlin, Cravioto, Frenk, Lopez, Galvan, Gomez and Janeway, 1958). Low levels of α and β liporproteins, total lipids, phospholipids and cholesterol have been observed in kwashiorkor children (Dean and Schwartz, 1953; Ramanathan, 1955; Chatterjee and Chaudhari, 1961). A lowering of total plasma amino nitrogen has been observed (Westall, Roitman, Pena, Ramussen, Cravioto, Gomez and Holt Jr., 1958), a greater reduction being seen in

tryptophan, cystine, valine, tyrosine, and methionine (Westall et al, 1958; Norton, 1960; Arroyave, Wilson, Funes, Behar, 1962). Low serum levels of vitamin A and carotene have been reported (Scrimshaw, Behar, Arroyave, Viteri and Tejada, 1956; Gopalan, Venkatachalam and Belavady, 1960; Chikhalikar, Magar, Patel and Patel, 1961; Reddy and Srikantia, 1966; Pereira, Begum, and Dumm, 1966). Plasma vitamin E has also been found to be reduced (Trowell, Moore and Sharman, 1954).

Activities of a number of enzymes are found to be altered in protein deficiency. Blood enzymes such as plasma esterase and lipase (Srinivasan and Patwardhan, 1952), serum amylase (Brock and Hansen, 1962) and liver enzymes such as xanthine oxidase, choline esterase, D-amino acid oxidase (Water low, 1963) are found to be decreased. Enzymes such as malic, lactic and glutamic dehydrogenases transaminase and cytochrome reductase were found to be unchanged in the liver biopsy specimens whereas liver alkaline phosphatase and catalase were found to be increased (Waterlow, 1963). Diminished activity of lipase, amylase and trypsin in the duodenum is also reported (Brock and Hansen, 1962). Serum alkaline phosphatase is found to show a decrease (Scrimshaw, Behar, Arroyave, Viteri, Tejada, 1956) or increase or no change (Dean and Schawartz, 1953; Waterlow, 1959) because of the differential effects of

calcium, protein and other deficiencies. For instance, in rickets alkaline phosphatase may be elevated, whereas in protein deficiency it may be decreased so that the effects of the two deficiencies may cancel out each other.

Extensive studies on histological changes brought about by kwashiorkor have been carried out by a number of workers (Ramalingaswami, Sriramachari, and Tulpule, 1952; Ramalingaswami, Sriramachari and Patwardhan, 1954; Waterlow and Weisz, 1956; Mendez and Tejada, 1961; Platt, Heard, Stewart, 1964). Structural changes found in the liver include fatty infiltration, fibrosis and degeneration of the hepatic cells. An increase in glycogen content and a decrease in protein and RNA contents of the liver have been reported. Divergent reports regarding the hepatic cholesterol levels of kwashiorkor patients have been made. While Ramalingaswami et al (1954) have reported an increase, Waterlow and Weisz (1956), Mendez and Tejada, (1961) and others have reported a decrease in cholesterol content.

Associated changes in intestine and pancreas have also been reported. In the latter, the acinar cells shrinks in size, the enzyme granules are reduced in number and there is a loss of basal proenzyme plate. (Scrimshaw and Behar, 1959, 1961). In the former, extensive atrophy with degeneration in the epithelial cells is noted. Since the

epithelium of the small intestine has one of the most rapid renewal rates and rapidly proliferating cells (Ramalingaswami, 1964), this impairment may be due to an inadequate supply of essential nutrients, especially the essential amino acids. Atrophy of these cells in turn may alter the permeability of the intestinal mucosa, which may result in improper absorption (Martin, 1968). Losses of endogenous nitrogen through the intestine are also greater in kwashiorkor. This might perhaps be the effect of altered permeability.

The association of arrested growth and mental retardation in children suffering from protein-calorie malnutrition has aroused world wide interest. Platt (1961) observes in this connection that "clinically, mental apathy is a constant feature of protein malnutrition". A severe calorie deficiency in childhood is associated with irreversible mental retardation according to Stoch and Smythe (1963). Delayed neurointegrative development in malnourished children has been reported by Cravioto, Delicardie, and Birch,(1966).

In contrast to kwashiorkor, nutritional marasmus is the result of undernutrition associated with a gross shortage of protein and calories. Protein calories may form more than 10% of total calories in the diets of marasmic children. The symptoms are muscle wasting and

lack of subcutaneous fat due to the deficient intake of both protein and calories. This is found to occur in infants due to underfeeding of the children with very dilute milk and other diluted formulas (Jelliffe,1968). Occurrence of marasmus, has seldom been reported from India but this may be because almost all the studies carried out seem to have been made in regions consuming rice. However, occurrence of marasmus is the major problem compared to kwashiorkor in countries such as Lebanon, Jordan and Egypt. The diagnosis and prevention of this condition is reported to be more difficult than that of kwashiorkor (McLaren, 1967).

Malnutrition is believed to be the main cause of high mortality rates during the pre-school years. The surviving ones may be blind, permanently stunted or mentally retarded. The cost of these consequences for the community can well be imagined.

The problem of malnutrition is further aggravated by the high incidence of infections such as small pox, dysentry, and poor treatment and rehabilitation of the child.

The poor diet of the child in the post-weaning period becomes further inadequate following an attack of small pox etc. because of the depletion of the already poor body stores, increased needs of nutrients and further

restriction of the already inadequate diet because of the ignorance of the mother. Following an episode of infectious disease, the child is often given only starchy gruels, thus making the diet poorer than the normal diet. Thus malnutrition increases susceptibility to infections and the latter often aggravates malnutrition (Scrimshaw, 1966).

As malnutrition is partly due to the poor availability of healthy foods and factors such as poor hygiene, its prevention is the concern not only of the nutritionist but also of the agriculturist, the food technologist and public health workers. To the extent that it is caused by ignorance regarding the proper use of available resources, it can be corrected by nutrition education.

Milk is by far the best weaning food. But the high cost of milk and its non-availability in many regions of the world limit its use especially in the low socio-economic groups. This is evident from the figures available on milk intake which is of the order of 80 to 140 g. in many of the diet surveys mentioned earlier. Reconstituted skim milk powder has been widely used in the treatment of kwashiorkor cases (Achar and Benjamin, 1953; Dean, 1953). Supplementation of skim milk powder is found useful in promoting better growth in Indian children (Aykroyd and Krishnan, 1937). In addition to milk, meat, fish and eggs are also sources of

good quality proteins, but they are in short supply except perhaps for fish in coastal areas. The overall shortage of these products and the realisation that vegetable proteins of complementary amino acid composition can be so combined as to result in mixtures of superior protein value have stimulated many studies for the production of alternate products.

Although milk is in short supply in most areas of the world, techniques for the production of milk powder have enabled the transportation of large quantities of milk powder from areas of production to those of need. Skimmed milk powder can be produced as a byproduct of the butter industry and has excellent keeping qualities, and the same reinforced with vitamins A and D has been used in many child welfare programmes sponsored by organizations such as CARE or UNICEF. But the supply of skimmilk powder can at best meet a small part of the need for suitable protein foods for young children.

Another development has been the technological processing of fish into fish flour. Fish proteins, like other animal proteins, are excellent sources of lysine, methionine and tryptophan. But processed fish proteins are found to vary in their biological value (Bender and Heizelden, 1957). Moreover, some studies suggest that not all the products are suitable for human use. (Cravioto, Guzman, Cravioto,

Suarez, Ma dela, and Massien, 1955; Carpenter, Ellinger, Munro and Rolfe, 1957). Fish proteins also pose problems in acceptability although the development of odourless products has been recently claimed (VioBin Corporation; F.I.R.I. South Africa). Although the addition of fish flour increases the protein value of cereals, their beneficial effects are no greater than those of legume supplementation on the basis of several studies carried out in this laboratory (Majmudar, 1965; Tambe, 1965). Further data on their shelf-life are lacking (Morrison and Campbell 1961). While they can supplement the usual protein sources to some extent, it is doubtful whether they can fill the protein gap.

Soyabean contains a good amount of protein of high quality (Payne and Stuart, 1944). The essential amino acid composition of soyabean (Parpia, 1966)[b] as compared to that of FAO reference pattern is shown below :

	Essential amino acids - g/g nitrogen	
	soyabean	FAO reference pattern
Lysine	0.42	0.27
Tryptophan	0.08	0.09
Phenylalanine	0.33	0.18
Cystine	0.10	0.13
Methionine	0.10	0.14
Threonine	0.24	0.18
Leucine	0.50	0.31
Isoleucine	0.37	0.27
Valine	0.33	0.27

Desikachar and Subrahmanyan (1949) showed that soya milk has a good supplementary value when added to poor cereal diets of children. Dean (1953) compared the progress of malnourished children treated with soya milk and cow's milk and obtained a good response with soya milk except for a slow rise in serum proteins. Similar results were obtained by Gomez, Ramos - Galvan, Cravioto, Frenk Pena, Morene and Villa (1957). Soyabean in combination with peanut in the ratio 1:1 and fortified with 1% lysine and 1% methionine was found beneficial in supplementing diets based on rice, maize and tapioca (Doraiswamy, Rao, Shankaran, Rajagopalan and Swaminathan, 1964). The rationale for the fortification with lysine is not, however, clear. But it is not easy to secure acceptance of soyabean by populations not accustomed to its use (Patwardhan, 1961). Moreover the agronomic details of cultivating it in many regions where protein malnutrition exists are yet to be worked out (Behar, Bressani and Scrimshaw, 1959). Attempts are now being made at the Amul Dairy at Anand to cultivate soyabean and to extend the supply of buffalo milk by mixing it with soyabean milk.

In India soyabean cultivation is limited whereas bengal gram and other pulses are extensively cultivated (Parpia, 1966a). Because of their higher protein and lysine contents as compared to cereals which are deficient in lysine, they can help to increase the quality and quantity

of proteins in cereal diets. Although pulse proteins have poor protein efficiency ratios when fed alone, their nutritive value as well as that of cereals is improved when they are fed in combination with cereals. (Chitre and Vallury, 1956; Phansalkar, Ramachandran and Patwardhan, 1957, 1958). Studies in this laboratory have shown that supplementation with a pulse such as bengal gram is as effective in improving the protein values of cereals as that with skim milk powder, fish flour or lysine (Tambe, 1965).

Roasted bengal gram powder given alone or with rice has been found effective in the treatment of kwashiorkor although the rise in serum albumin was slow compared to that obtained with skim milk powder treatment (Venkatachalam, Srikantia, Mehta and Gopalan, 1956). Similar results have been obtained during trials in the All India Institute of Hygiene and Public Health, Calcutta and the paediatrics department, Madras (ICMR Report No. 46, 1963). A mixture of roasted bengal gram flour and skim milk powder in the ratio 4:1 was found good in the treatment of kwashiorkor cases and also during field trials (Ganapathy, Swaminathan, Taskar, and Rao, 1961).

Another promising protein source is groundnut and groundnut meal. A groundnut curd preparation was found beneficial in supplementing rice diets (Subrahmanyan, Reddy, Moorjani, Sur, Doraiswamy, Sankaran, Swaminathan,

and Bhatia, 1954). Low fat peanut flour along with legumes or skim milk powder has been found useful in the treatment of kwashiorkor cases (Jayalakshmi and Mukundan, 1961). The multipurpose food developed at the Central Food Technological Research Institute,Mysore is based on combinations of defatted groundnut meal and bengal gram in the ratio 3:1. Supplements of multipurpose food were found to improve the nutritive value of the poor rice diet (Subrahmanyan,Joseph, Doraiswamy, Rao, Sankaran, and Swaminathan, 1957; Subrahmanyan, Doraiswamy, Bhagwan, Rao, Sankaran and Swaminathan, 1959). Biscuits made of a mixture of groundnut flour, corn and skim milk powder have been found effective in the treatment of kwashiorkor cases (Clegg and Dean, 1960). The high protein biscuits developed at Mysore are prepared from groundnut flour, wheat flour, and sugar fortified with vitamins and minerals (Karnad, 1961). Recently, a method of preparing protein from groundnut-oilseed meals has been reported (Bhatia, Parpia, and Baliga, 1966). Balahar, a recently developed food is based on a combination of 75% wheat flour, 20% solvent extracted groundnut and 5% skim milk powder fortified with vitamins and minerals (Berg personal communication). Other products based on oil cakes from sesame and coconut have also been developed and evaluated (Venkatachalam and Srikantia, 1961; Tasker, Rao, Indiramma, Swaminathan, Sreenivasan and Subrahmanyan, 1962).

Several processed food mixtures based on locally available grain and oil cake and suitable for young children have been developed in different parts of the world. The 'Incaparina' mixtures developed in Central America are judicious combinations of corn, maize, decorticated sesame and Gossypol-free cotton seed flour, fortified with yeast, vitamins and minerals. Clinical and field trials with the products showed that the tolerance and acceptability were good. Nitrogen balance studies carried out on 1-5 year olds in a late stage of convalescence suggest that at levels of protein intake above 2g. per kg. body weight, the products were as good as milk diets. However, at levels of intake below 2 g. per kg. body weight, milk was found superior (Scrimshaw, Behar, Wilson, Viteri, Arroyave and Bressani, 1961). One of the formulations is extensively being marketed in Central America.

Products such as 'Laubina' in the middle east (Tannous, Cowan, Rinnu, Asfour and Sabry, 1965; McLaren, Asfour, Cowan, Pellett and Tannous, 1967) and 'pronutro' in South Africa (Odendaal, 1965; Kapsotis,, 1967) are based on similar combinations of vegetable foods with or without addition of animal foods.

Though protein foods of the type described above can be manufactured from soyabean, cotton seed, coconut and

similar oil seeds and oilseed meals, the widespread use of these in the diet of pre-school children of developing regions requires a rapid development of food technology, transportation facilities and education of the people in the use of these products (Abbott, 1965).

The poor keeping quality of oilcakes poses problems in their use by the housewife. Groundnut can, however,form a valuable addition to the weaning food along with pulses in the form of a paste or milk prepared from the roasted and skinned kernels. It can impart a creamy texture and nutty flavour to gruels prepared from a cereal-pulse mixture. Care must be taken to ensure that they are free from mold contamination as the mold. Aspergillus flavus that is sometimes found on groundnut, is toxic (Milner, 1966).

Improvement in the quality of proteins of cereals and legumes can also be achieved by the addition of several of the limiting amino acids. Scrimshaw and his associates have shown significant improvement in nitrogen retention by the addition of tryptophan, lysine, and isoleucine to corn masa flour (Scrimshaw, Bressani, Behar and Viteri,1958; and Bressani, Scrimshaw, Behar and Viteri, 1958). Several studies have shown that addition of lysine to wheat products results in an improvement in their protein quality (Westerman, Hays, Schoneweis, 1957; Westerman, Kannarr, and Rohrbough, 1957). Lysine-fortified bread, soups and breakfast

dishes are already being introduced in the market by several commercial firms. Similarly, the quality of rice proteins and rice products are improved by the addition of 0.2% lysine and 0.2% DL-threonine (Kik, 1956a, 1956b). However, supplementation with aminoacids without correcting deficiencies of the limiting amino acids of the diet may not produce beneficial effects, but actually produce an adverse effect (Harper, 1959; Fisher and Shapiro, 1961). Increasing the second deficient amino acid without correcting the deficiency of the first limiting amino acid is found to be of no value, as might be expected. When foods are fortified with the first limiting amino acid, it is usual to adjust the dose so that the level is increased to that corresponding to the level of the second limiting amino acid.

Enrichment of foodstuffs with minerals and vitamins is being carried out in many countries. When specific vitamin or mineral deficiency exists, such procedures have proved beneficial. Use of enriched flour and iodised salt have helped to eradicate mineral vitamin deficiencies and goitre in many parts of the world. But enrichment with individual nutrients such as calcium or vitamin A may not help when the overall quality of the food is poor. Supplementation of calcium to a low calcium diet which is deficient in other nutrients is found to have no

beneficial effects (Bansal, Rau, Venkatachalam, and Gopalan, 1964). Similarly, addition of vitamin A alone in the diet of kwashiorkor children did not bring about any change in the level of vitamin A in blood (Gopalan, et al, 1960). In this country the bulk of the food consumed in rural areas is consumed locally so that enrichment at source is almost an impossible proposition. Further in the case of wheat and other grains purchased as such rather than as flour, reinforcement with nutrients is not very easy.

As pointed out earlier, the production and distribution of processed and enriched foods may not be possible on a sufficiently large scale in the near future. It seems necessary therefore to identify cooking and processing which can be employed by the rural housewife and which can increase the suitability and nutritive value of foods consumed by young children.

The flavour, texture, digestibility and vitamin content of foods can be improved by methods such as germination, roasting, and fermentation etc. which can be used either in the home or large scale preparation of processed foods. Germinated and roasted cereals and pulses acquire a malty flavour. At the same time these processes bring about destruction of trypsin inhibitors and also improve

the nutritive value. Vitamins such as thiamine, riboflavin, ascorbic acid and nicotinic acid are found to be increased to a considerable extent. During germination, enzymes such as phytase, cellulase, amylase and protease appear and they help to break-down phytate, and cellulose and to convert starch and proteins to more easily digestible products (Bhagwat and Rao, 1942; Aykroyd and Doughty, 1964; Dhand, 1964). Many of these changes also take place during fermentation. An increase in thiamine, riboflavin, nicotinic acid and improvement in texture, taste, and digestibility have been found with fermentation (Radhakrishna Rao, 1964; Rajalakshmi and Vanaja, 1967). However, these procedures are not adequately exploited by the common man or by institutions such as hospitals, hostels and schools.

Although as pointed out earlier, several processed foods suitable for children have been developed and evaluated, whole day diets for young children based on locally available foods which can be prepared by the mother in rural areas with simple kitchen equipment have not been formulated, leave alone their evaluation. As pointed out earlier,it is essential to do this as processed foods cannot be expected to meet the needs of rural areas in the near future.

The present study was undertaken to formulate and evaluate such whole day diets based on locally available foods for pre-school children. The formulations were based mainly on animal experiments carried out in this laboratory or elsewhere. The dietary principles used in the formulations were tested by animal experiments to the extent possible. Whole day diets cooked according to these formulations were also evaluated with animal subjects. The diets formulated were fed to pre-school children for 6 month periods in two successive years and studies made of the effects of these diets on their physical, clinical, biochemical and radiological status. These studies are incorporated in this thesis.