



**REVIEW OF  
LITERATURE**

## Chapter-II

### REVIEW OF LITERATURE

The relevant literature has been reviewed under the following heads and sub-heads:

- I. Nutrition and growth during infancy and early childhood in developing countries.
- II. Protein energy malnutrition and its etiology:
  - II.1. Composition of weaning foods
  - II.2. Frequency of feeding
  - II.3. Microbial quality of weaning foods.
- III. Practical approaches to lower dietary bulk:
  - III.1. Physical methods -
    - 1) Addition of fat
    - 2) Roller/Drum drying
    - 3) Extrusion cooking
    - 4) Roasting
    - 5) Puffing
    - 6) Flaking
  - III.2. Chemical methods -

- 1) Treatment with enzymes
- 2) Germination / Malting and its effect on nutritional and biological value of food.

#### IV. Development of supplementary foods at -

IV.1. Village/Community/Household level using simple techniques. Fully malted mixes, partially malted mixes and development and use of Amylase-Rich Foods (ARF).

#### I. Nutrition and growth during infancy and early childhood in developing countries

A newborn is entirely dependent on breast-milk for sustenance during the first few months of life. The nutritional adequacy of human milk for supporting normal growth and development during the first two to three months of life has been firmly established, and numerous studies have concluded that breast-milk alone provides nutrition through the sixth month of life (Duncan et al 1984; Hitchcock et al 1985; Isherwood et al 1988). Even in Biblical times, breast-feeding was recognised as the best feeding for infants. After the Pharaoh's daughter found Moses in the bulrushes, she agreed that a wet nurse was necessary and Mose's own mother unknowingly was recruited. However, artificial feeding was resorted to by the less affluent who could not afford wet nurses. A major stimulus to the artificial feeds arose in the mid 18th Century with the onset of the Industrial Revolution when women found they could earn more in factories than as wet nurses (Barness 1987). Milk of other mammals was used as a breast-milk substitute (King and Ashworth 1987).

Mortality was very high in artificially fed infants. In the first few weeks of life it was almost 100% in infants fed cow's milk. When diluted cow's milk was fed, mortality was less frequent. However, it failed to support adequate growth.

Examination of the composition of breast-milk indicated a low concentration of protein which was surprising. However, the high calorie density of milk (70 Kcal/100 ml) explained its ability to promote rapid growth in infants (Barness 1987). Breast-fed infants have been found to grow well even on lower intakes of breast-milk (Poskitt 1987).

In a study to evaluate the nutritional adequacy of breast-milk Whitehead, Paul and Rowland (1980) followed breast-feeding mothers and their infants in a well-off environment in Cambridge, England, and in a rural environment in the Gambia where childhood malnutrition is rampant. Both groups of infants showed weight gains more rapid than expected for the first 6 to 8 weeks of life. After that, growth rates slowed particularly in Gambian infants. Both groups of women produced sufficient volume of milk that initially satisfied the infants' needs. Maximal milk volumes were achieved by the second month of life and after that the volume of milk produced by the women in both the groups fell gradually. The milk intakes of the infants in both Cambridge and the Gambia were inadequate after 3 months as compared with the recommended intakes for the age in question. Waterlow and Thomson (1979) also observed that the breast-milk output appeared inadequate to meet the energy needs of infants over 3 months of age.

Differences in the growth pattern of breast-fed and artificially fed infants were observed particularly after 3 months of age. The artificially fed

infants thrived better than those who were exclusively breast-fed (Hitchcock et al 1985). These findings are in confirmation with the reports from Sweden (Mellander et al 1959), North America (Paiva 1953) and Australia (Shade 1980). Thus when breast-milk ceases to meet the requirements of the growing infant his diet needs to be supplemented with other foods viz. non-milk foods. Gradually the infant is fed adult diet and the whole process is termed as weaning. The weaning foods introduced in the infant's diet must have an energy density as high as that of breast-milk for sustained accelerated growth. However, it is not so as is obvious from the high prevalence of Protein Energy Malnutrition (PEM), morbidity and mortality among the infant and toddlers in all the developing countries. **The problem of PEM has surprisingly remained constant despite best efforts to combat it.**

## II. PEM and its aetiology :

When Williams described Kwashiorkar in young children in Ghana some 59 years ago, she diagnosed it as a nutritional disease, adding cautiously "... in which some amino acid or protein deficiency cannot be excluded". The children who developed the disease did so after weaning, when they were fed starchy porridges rather low in protein, and they were cured by milk. Over the past several years it was generally held that the two extreme forms of malnutrition viz. Kwashiorkar and Marasmus occur due to protein and energy deficit respectively (Waterlow and Payne 1975).

The first serious attack on the theory came from Gopalan in India. In a prospective study of children in a poor community "food supplementation" eradicated both, namely the symptoms of Marasmus as well as Kwashiorkar

(Gopalan 1968). It is well understood now that a primary energy deficiency in starving children leads to immobilisation of stored proteins resulting in a secondary protein deficiency. Survey of food intakes of preschool children in India confirmed the adequacy of diet with respect to protein while the calorie intake was inadequate (Jones and Periera 1972). Martorell et al (1978) have shown improved growth rates in an energy deficient population on providing an energy supplement.

From the above review it is evident that it is the 'food gap' that results in undernutrition in the weanling.

The aetiology of PEM has been traced to the following dietary and associated factors:

- 1) Composition of weaning foods
- 2) Frequency of feeding
- 3) Microbial quality of weaning foods.

#### **II.1. Composition of weaning foods :**

In most cultures traditional weaning foods are non-milk family foods, based on the local staple usually a cereal such as corn, sorghum, wheat or rice. Sometimes starchy roots like cassava constitute the staple (Mellander and Svanberg 1984).

Cereals are reported to form 77% by weight of the total diet of preschool children in South India where rice forms the staple (Jones and

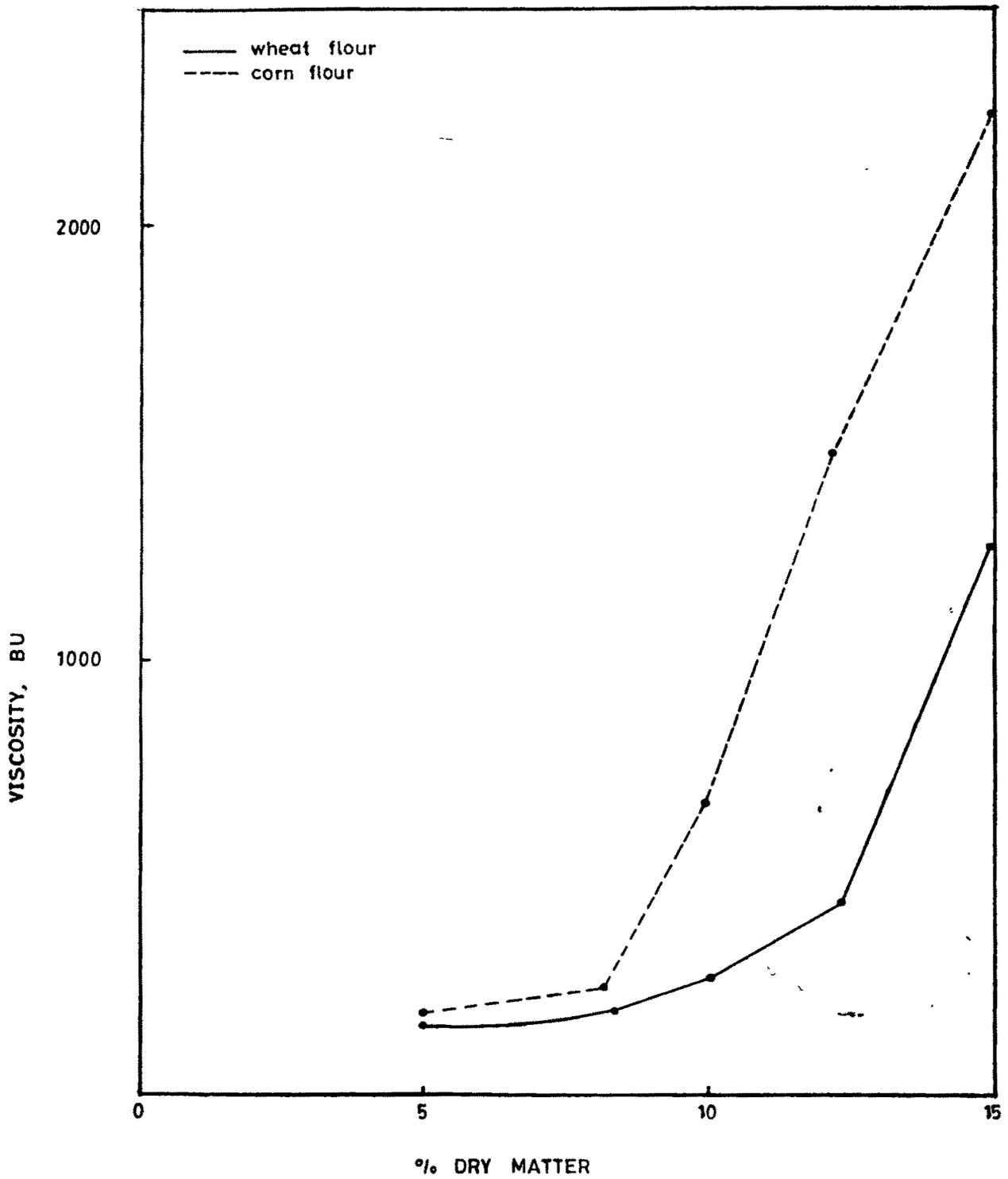
Periera 1974). Similarly, children fed a mixed diet were found to derive 70-80% of their total energy requirements from cereals, while energy dense foods like fats and oils formed a very small portion of their diet (NNMB 1983). These cereals/cereal flours are generally cooked in the form of porridge or gruel for feeding young children.

Starch is a major component of all the cereals, roots and tubers. Starch is present in granular form in diversity of shapes and sizes which is characteristic of the source from which it is derived. When starch granules are progressively heated in water, irreversible hydration and swelling takes place at a certain temperature. Further heating beyond this 'gelatinisation' temperature causes greater swelling typical for each starch. When the starch paste cools, a three dimensional network is formed. At the molecular level water gets trapped and bound to the polar groups on the starch (Whistler and Paschall 1967). It is this trapping and binding of water which imparts 'high viscosity' to the cooked product. In order to keep the thickness of the final product within desirable limits the concentration must be lowered by dilution with water. Thinning by addition of water leads to an increase in volume. This high viscosity/high volume characteristic of starchy foods is termed as 'dietary bulk'.

Dietary bulk of each starch base varies. For example, a gruel from maize flour yields much higher viscosity as compared to that from wheat flour when the same amount of flour is used (Figure 1).

Most traditional gruels with desirable consistency cannot hold more than 10-12% flour. These traditional gruels have an energy density of 1 Kcal/g

THE VISCOSITY OF GRUELS FROM WHEAT AND CORN FLOUR WITH DIFFERENT CONCENTRATIONS.



SOURCE: HELSTROM ET AL 1981

Fig. 1

while the common weaning foods in Western Europe have an energy density of 2 Kcal/g (Ebrahim 1983) Though theoretically it implies that a young child fed traditional starchy porridge needs to consume twice as much as his Western counterpart, very few attempts to test the hypothesis have been made.

Nicol (1971) was the first to validate the role of 'dietary bulk' based on actual food intake studies. The quantity of food required to cover the energy needs of a 1-3 year old was an estimated 690 ml - 1390 ml and that for children 4-6 years of age between 900 ml and 1650 ml. The young one with its low gastric capacity can consume the above amounts of food if fed thrice or more times in a day. The gastric capacity of children has been calculated from intake studies on milk based formulae. A child of 4 months can consume a litre of milk. However, in milk or milk formulae, water is free and gets absorbed quickly. While in the starchy porridges water is in bound form and can be absorbed only after degradation of starch granules by digestive amylase. This process delays the gastric emptying and prolong the interval between two meals on a starch based diet.

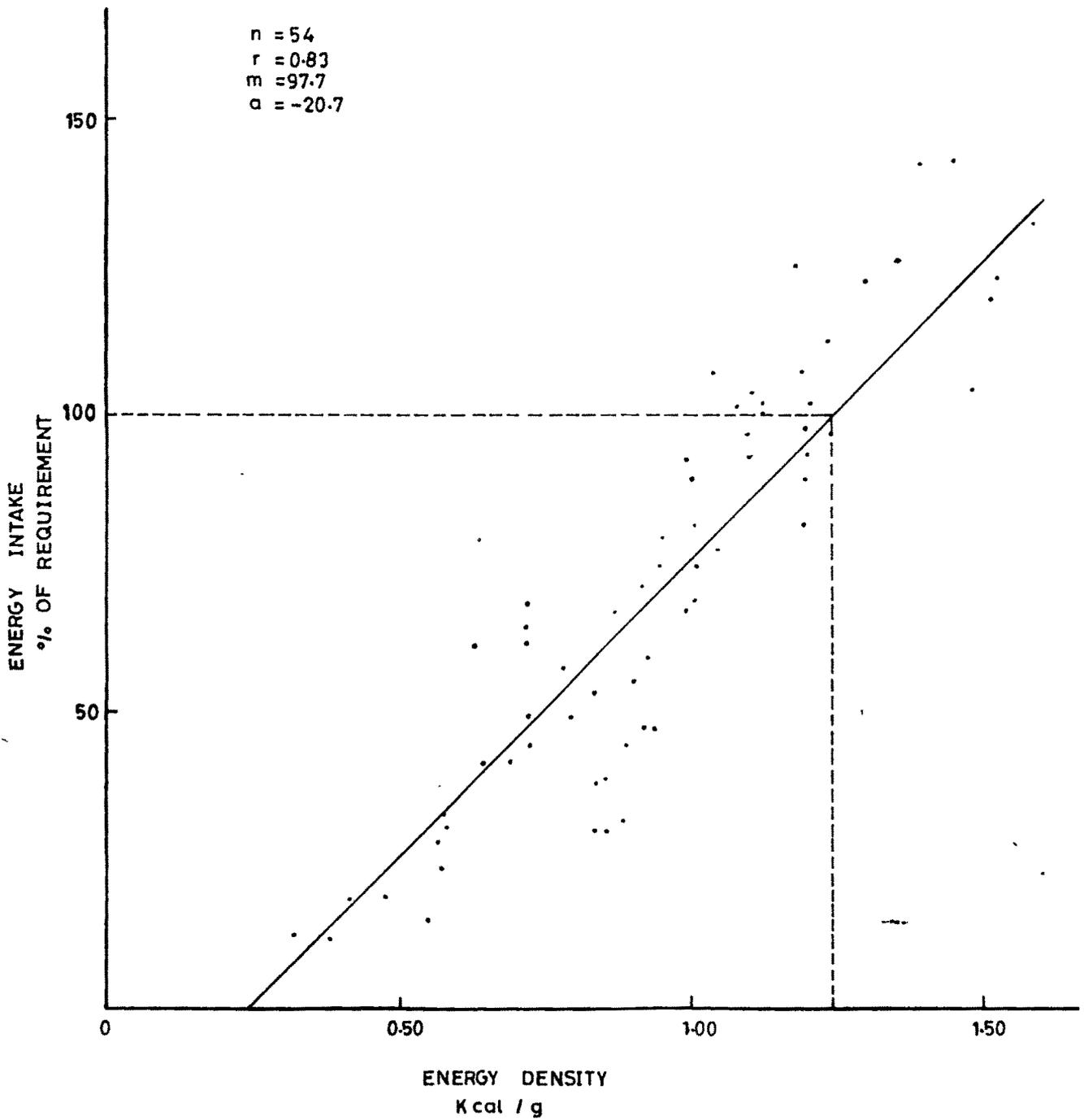
Rutishauser (1974) identified poor appetite, low frequency of feeding (2-3 times a day), low energy density of porridges prepared from plantain and cessation of breast feeding as the major factors for inadequate energy intake in Ugandan children. Even in children with good appetite the food intake was much below the requirements. Interestingly the data also show that the energy deficit on discontinuation of breast feeding could not be compensated for with additional intake of solid foods other than milk.

Preschool children fed rice based diets ad libitum could consume at the most three meals a day and only 66% of these subjects could eat enough to meet their caloric requirements (Jones and Periera 1972). The above evidence confirms the decisive role of energy density of weaning foods.

Actual energy intake (as % of requirements) as a function of energy density was calculated from surveillance in villages and nutrition rehabilitation centres in Tanzania. A significant positive correlation ( $r = 0.83$ ) was observed between the two factors. On an average energy density of about 1.25 Kcal/kg of prepared food was needed in order to meet the estimated daily energy requirements and more than 70% of the children were eating meals with lower energy density (Figure 2). Increasing the feeding frequency did not enable the children to eat adequate amounts of a low density diet (TFNC 1978).

Araya et al (1983) studied the corresponding food intake in preschool children fed diets of varying energy density viz. 0.47 Kcal/g to 1.90 Kcal/g. The subjects modulated their total energy intake by modifying food intake as indicated by the highly significant and negative correlation coefficient between the two factors. However the children fed very low energy density diet (0.77 Kcal/g and below) could not modulate their food intake to cover the energy requirements. It could probably be due to the reason that their intakes were near maximal gastric capacity. The situation called for developing low cost weaning foods based on local staples with adequate calories, low bulk, i.e. desirable energy density and consistency keeping in mind the limited consumption capacity of children.

DAILY ENERGY INTAKE AS % OF ENERGY REQUIREMENTS IN RELATION TO THE DIETARY ENERGY.



SOURCE : TFNC 1978

Fig. 2

An analytical approach through linear programming with the above constraints was used to develop appropriate weaning foods for developing countries using the regional staple. The composition of various diets developed is given in Table 2.

**Table 2 : Least-cost diets calculated for children 1-3 years of age**

Foods	Northern Nigeria	Southern Nigeria	Mexico	India	Turkey
Millet	148	-	-	-	-
Yams	0	100	-	-	-
Cassava	0	50	-	-	-
Maize	-	95	191	-	-
Rice	-	-	0	166	-
Wheat	-	-	11	35	217
Oil	63	49	42	41	48
Cowpeas	25	68	-	-	-
Dry beans	-	-	17	0	2
Chick peas	-	-	-	18	0

Source : Chamberlin and Stickney (1973)

As can be seen from the table a young child fed least cost low bulk rice based diet will have to consume 260 g of raw weight of food. It is obvious again that overcoming bulk constraints is most difficult since most foods that provide calories and proteins at low cost such as cereals have low concentration of these nutrients and therefore have a greater bulk. Increasing the fat content will lower the bulk considerably by lowering viscosity and increasing energy density but simultaneously increase the cost. The calculated least-cost diets include 41 g of fat and hence may not be affordable by a poor mother. The above discussion amply explains the role of composition of diet on food intakes in young children.

## II.2 Frequency of feeding :

The high volume/low energy density character of the traditional gruels calls for frequent feeding i.e. at least thrice or more per day in order to meet the child's energy requirements. Mothers have been taught the preparation of balanced weaning foods and importance of frequent feeding. All these attempts have met with little or no success since the advice given to the poor, overworked rural mothers is highly impracticable. Therefore, the young child continues to get at the most 2-3 meals a day (Tomkins et al 1988). It has been reported that the poor mother from rural Gujarat (India) who works away from home, hands over a piece of rotla (unleavened wheat bread) to the young child when the whole family is having their meal or feeds the child a handful of khichadi (rice + pulse preparation) from her plate. Consumption of food inbetween meals depended on availability of ready-to-eat food, availability and inclination of the person taking care of the child (Wijga et al 1983) Thus low frequency of feeding coupled with the dietary bulk is responsible for undernutrition.

### II.3 Microbial contamination of weaning foods :

In underdeveloped and developing countries children are malnourished or dying from Protein Energy Malnutrition (PEM) aggravated by weaning diarrhoea as early as three months of age (Jelliffe and Jelliffe 1970; Mathur and Reddy 1983; Rowland 1986). An estimated 5 million infants and children die of acute watery diarrhoea while PEM claims 3 million lives annually in the same age group (Evans 1986). The problem is that once the weaning process is initiated, usually with unhygienic, nutritionally inadequate preparations, breast-fed infants suffer a high level of diarrhoeal morbidity, well-termed weaning diarrhoea (Gordon et al 1963). Thus, besides the availability of food its microbial quality is equally if not more important for good health and nutrition. A study from Peru reported that on one hour of storage, fecal bacteria increased three-fold in weaning gruels and purees made from potato, wheat, maize and bananas (Black 1989). Studies from Bangladesh (Black and Brown 1989), India (Mathur and Reddy 1983), Kenya (Van Steenberg 1983) and the Gambia (Rowland 1978) have also shown evidence of heavy microbial load which increases further on storage. It thus becomes imperative to examine the factors affecting the microbial quality of infant foods and identify those factors/practices which promote microbial safety of the same.

Pertet et al (1988) surveyed the food preparation methods for the most commonly used weaning or introductory foods viz. tea, cereal, porridge, water in a Kenyan rural community setting. Presence of *E. coli* at the time of consumption was used as an indicator of fecal contamination. The authors observed that a cooking time of 5-60 minutes and a temperature of 30°C - 70°C

or more was used for cooking. About one-third of the foods were cooked at a temperature of more than 70°C for more than 1 hour. However, neither the cooking time nor temperature was found to influence the levels of contamination. This suggests that various handling procedures such as cooking and storing have a bearing on the microbial quality of the product. Observation of Simango (1988) corroborate the above findings. A study in a community setting in Zimbabwe reported milk to be the most frequently contaminated food item (57%) followed by boiled corn (50%) and ORS solution (36%). The food was generally stored for less than 12 hours in the cooking pot. There was slightly more contamination of porridge stored in other containers than of that stored in the cooking pots (16 vs 13%). Contamination was highest when the samples were stored in a clay pot (36%) or a glass bottle (33%).

The storage time also had profound influence over the level of contamination of foods. Over 50% of the samples were contaminated when stored for 48 hours or more (Simango 1988).

Pertet et al (1988) reported the presence of *E. coli* in 13% of freshly prepared foods which increased to 18% on storage for 12 hours or more. They further observed that about 75% of the infants were fed from a cup and spoon, over 16% were bottle-fed and another 7% hand-fed. Contamination was least when cup and spoon was used (13%) than when the mode of feeding was bottle (14%) or hand (18%). The high levels of contamination observed in samples cooked at high temperatures was due to the addition of cold milk or leftover weaning food by mothers to cool it, thus, increasing the microbial load.

It is also interesting to note that the milk samples and weaning food samples collected from low income group (LIG) families showed higher bacterial contamination as against those obtained from high income group (HIG) families in India. Sixty percent of the samples collected from LIG were unacceptable while only 15% were so in HIG. The total bacterial count, *E. Coli* and *S. auereus* were significantly higher in milk samples obtained from LIG than those from HIG and the microbial quality was found to deteriorate further on storage. The handwashings showed the presence of *E. coli* and *S. auereus* the quantity being similar in both the groups (Mathur and Reddy 1983). Rowland et al (1978) have reported similar findings from a study of traditional weaning foods in a village in Gambia. The study also reports lower levels of *S. auereus*, *B. cereus* and absence of *Cl. welchii* in biologically acidified milk but they were present in appreciable amounts in the traditional weaning foods. The last observation is of importance especially in an underprivileged community where a mother has limited time, energy and fuel and cannot feed her baby with freshly prepared food at each meal.

There is considerable evidence which suggests that fermentation of cereal porridges significantly reduces the chances of contamination. Fermented sorghum based porridge from Lesotho (Nout et al 1988; Sakoane and Walsh 1988), maize dough from Ghana (Mensah et al 1991) and soya-bean tempeh from Indonesia (Wang et al 1969) have shown anti-microbial action against a variety of diarrhoeal pathogens viz. *E. coli*, *S. typhi*, *Campylobacter jejuni* *shigella sp.*, *Lactobacillus sp.* Fermented maize dough was found to be inhibitory to four strains of *Shigella flexneri* (Mensah et al 1988). Mensah (1991) has reported the inhibition of inoculated enterotoxigenic *E. coli* (ETEC) by

fermented maize dough. The cooking process was found to reduce the anti-microbial effect of the fermented maize dough on both *Shigella flexneri* and *ETEC*. Nout et al (1988) described the inhibition of a single strain of *S. typhimurium* with inhibitory activity remaining unaltered on cooking. Mbugua (1988) showed a reduction in the level of coliform during 'uji' fermentation of maize meal. The inhibitory effect of the cooked product was not studied. Wang et al (1969) studied tempeh, a fermented soyabean product and reported a loss in antimicrobial activity against *Staph. aureus*, *B. subtilis* and *Kl. pneumoniae* after heating. Fermentation is also known to reduce the levels of aflatoxin during the fermentation of sorghum-based porridge from Nigeria (Dada and Muller 1983). Hydrocyanic acid which occurs naturally in cassava and sorghum is reduced by 44% and 70% respectively during fermentation (Ketiku et al 1978; Dada and Dendy 1988). It was initially proposed that the reduction of pH was the main factor responsible for inhibition of bacterial growth, but it has been demonstrated now that the antimicrobial factors were heat-labile and precipitable by ammonium-sulphate, suggesting a protein substance, possibly an antibiotic. The supernatants of fermented foods showed anti-microbial property. This suggests that there may be differences in the anti-microbial properties of fermented foods based on the method of preparation viz. throwing away of water at each stage of the fermentation process as in Nigeria while retention of the steep water in Ghanaian fermented products. These need to be substantiated by systematic studies (Mensah 1991).

The fermented foods have yet another important attribute i.e. they yield a low viscosity product on cooking which enables incorporation of

solids at a higher level to obtain a more nutrient dense product. Similarly liquification of thick cereal porridges can be achieved by incorporating small quantities of flour from germinated cereals. Germination of food grains has been reported to increase the level of contamination. Harmon et al (1987) reports that 57% of the unsprouted seeds under study viz. alfalfa, mung and wheat were contaminated with *B. cereus*. Mung beans were contaminated more frequently. When these food grains were germinated in 'Home Sprouting Kits'. The number of pathogens was found to increase dramatically during sprouting in wheat and reached a level ( $>10^5$ /gm) likely to cause food poisoning in 58% of the samples examined. Mung beans and alfalfa were found to be poor substrates for the growth of *B. cereus*.

Washing the mung bean sprouts thrice and cooking at 95°C for 20 minutes reduced the contamination by one log unit. However, this procedure was not effective in lowering the *B. cereus* count to safe levels in wheat. This was essentially due to the abundant root hair or the kernel which made the washing procedure less effective.

Microbiological data on porridges prepared from sorghum and liquefied with germinated sorghum flour show that the unfermented product supported rapid growth of heat resistant bacterial spores and of added *S. typhimurium*. When lactic fermented sorghum porridge was the basic ingredient, the bacterial spores could not grow and the added *S. typhimurium* were to some extent destroyed (Nout et al 1988; Svanberg et al 1992). Porridges were prepared from rice with and without the addition of wheat Amylase-Rich-Food. *Shigella flexineri* and enterotoxigenic *Escherichia coli* were inoculated into both the porridges. The ARF treated porridge did not favour

further multiplication of these micro-organisms (Wahed et al 1993). However, most of the above studies have not examined the prevalence of diarrhoea in the population under study. Mere presence of *E. coli* cannot be regarded as harmful; but presence of *E. coli* of fecal origin can be considered a risk factor. Therefore, careful typing of the micro-organisms is necessary alongwith simultaneous survey for surveillance of diarrhoea. The above review emphasises the importance of enhancing the energy density, increasing the feeding frequency and careful handling and boiling of food prior to each serving in order to alleviate PEM in the weanling. However, the futility of advise to feed frequently is also evident. Therefore, it is necessary to identify a technology which would be feasible under the given constraints of time, energy, fuel and money.

### **III. Practical approach to lower the dietary bulk**

Since 'dietary bulk' is due to the presence of starch and its peculiar structure, it follows that a modification of the starch structure can lower the bulk. Starch can be modified by physical or chemical methods.

#### **III.1 Physical methods :**

##### **III.1.1 Addition of fat**

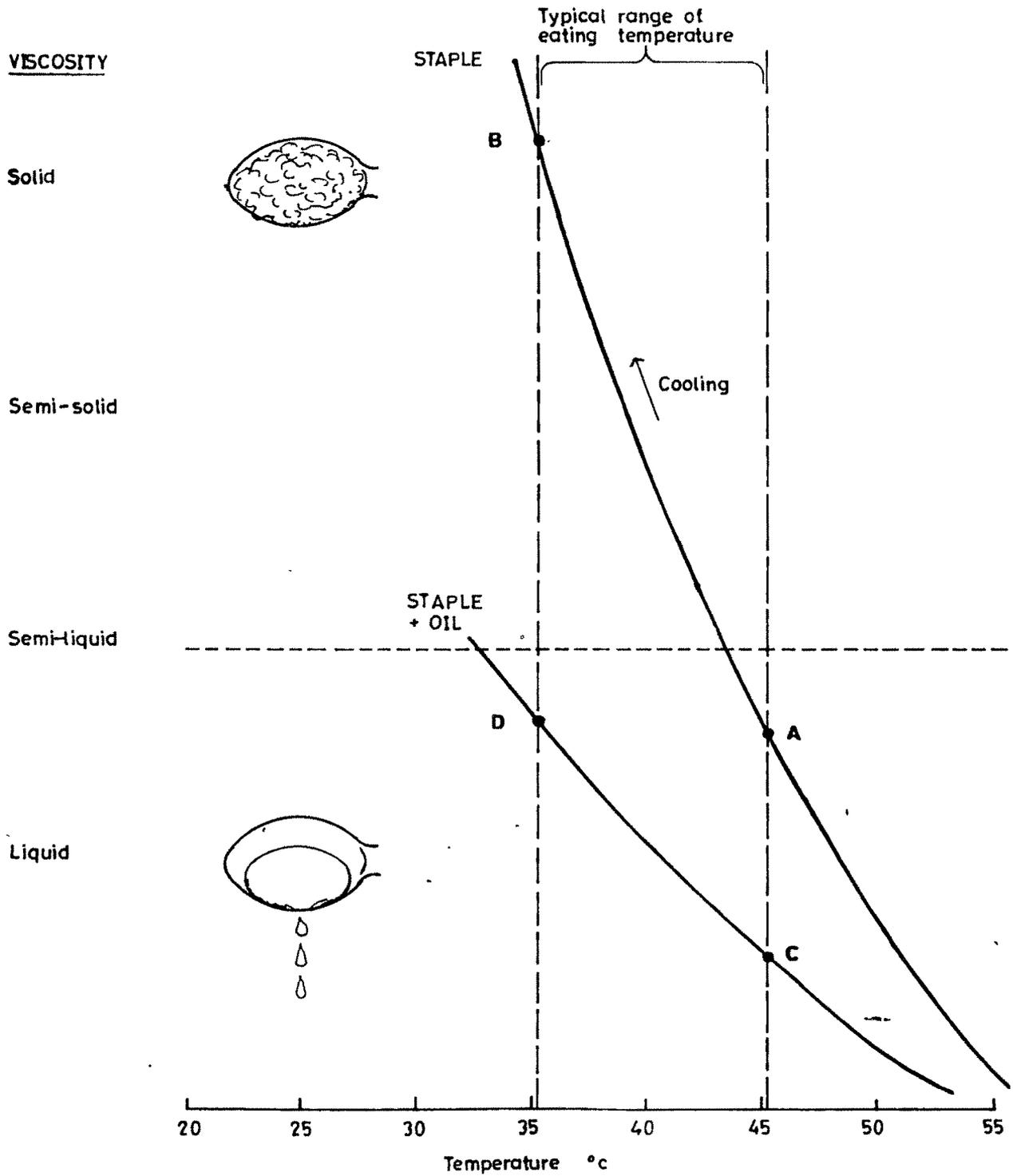
Addition of fats and oils lowers the bulk by increasing the energy density and also has an important effect on the viscosity of the gruel. Fat coats the starch granules and does not allow starch-water binding to take place thus lowering the viscosity of the resultant product. The milk-based diets are high in fat content as compared to the traditional cereal-based diets. A young child

fed milk-based diets derives 66% of energy from fats vis-a-vis 2-18% when fed cereal-based diet. The mean daily intake of solids was 330 ml vs 717 ml in milk-based formula fed and a traditional weaning diet fed group respectively. Children offered traditional diets were fed ad libitum 5 times daily and yet had a lower energy intake (Rutishauser and Froom 1973). Addition of 2 teaspoons (10 g) of oil to a maize-based S. American diet increased the energy density by 37%. Consumption of this diet over three meals was adequate to meet the energy requirements (FAO 1977). Thus when it is impossible to raise the quantity of food consumed due to the inherent bulk property, increasing the energy density is the only other solution.

In the temperature range of 35°-45°C (eating temperature) starchy foods solidify further. However, addition of fat or oil produces a liquid gruel at a lower temperature as demonstrated in Figure 3.

Addition of fat improves the palatability of food. Foods containing upto 60% of solids as fat are within 'physiological limits' as well as 'palatability tolerance zone' (Church 1977b). It is known that a high fat meal has a high satiety value and hence the child may feel satisfied before having eaten sufficient amounts (Dearden et al 1973). Secondly, a high energy density meal slows the rate of gastric emptying thereby prolonging the interval between two meals (Hunt and Stubbs 1975). Thus a very high fat meal may lower the intake per sitting and the frequency of meals. This aspect needs to be studied systematically. Though fats and oils are twice as energy dense as the starchy foods at the same time they are 8-10 times more expensive. A poor mother may therefore not be able to incorporate them beyond a certain level. Thus addition of fat cannot be a practical approach to alleviate the dietary bulk of traditional weaning foods.

**THE RELATIONSHIP BETWEEN TEMPERATURE AND FOOD VISCOSITY WITH AND WITHOUT THE ADDITION OF OIL.**



SOURCE : CHURCH 1977 b

**Fig. 3**

### III.1.2 Roller/Drum drying

Roller/Drum dryers consist of two counter-rotating, smooth-surfaced drums which are heated by steam. A precooked slurry (90% water) of cereal and other suspended ingredients is spread in a thin layer on the surface of the drums which dries quickly as the drums rotate. The dried product is scraped off the drums' surfaces before they are recoated with a slurry. Ultrastructural changes leading to starch breakdown take place during the process to yield a finished product with lower swelling capacity (Doublier et al 1986). Sometimes enzymes (amylase) are added to partially breakdown the starch and give a lower slurry viscosity, improved digestibility and sweetness. The drum dried products have low bulk, require reconstitution with hot water or milk and save time, energy and fuel (Harper and Jansen 1985).

Spray drying is yet another industrial process for manufacturing highly soluble, low viscosity weaning foods. The procedure is similar to drum drying except for the type of dryer used. A spray dryer consists of a large chamber through which hot air is blown. The precooked product is sprayed (atomized) into the hot air where the droplets dry and settle out to give a dried powder. The droplets in a spray dryer remain relatively cool during the drying process, improving the flavour of the finished product and solubility of the protein ingredients (Harper and Jansen 1985).

### III.1.3 Extrusion cooking

Extrusion cooking has been the most popular method and method of choice since the advent of low cost extruders. A variety of cereal and legume ingredients are cooked at high temperature (150-160°C) for short periods of time

(60-120 secs) at a moisture level of 15-25%. The extruder consists of a rotating screw which forces the product through a discharge die. Once cooked, the product is coarsely ground, mixed with a vitamin/mineral fortification, optionally with non-fat dry milk. The partially cooked flour is prepared into a gruel by addition of potable water (Harper and Jansen 1985). The reconstituted product has a lower viscosity than the drum-dried product at similar solid contents level (Doublier et al 1986).

Gruels prepared from extruded corn-soya blend (CSB) had a lower viscosity than the gruels from raw CSB. The former had a higher calorie density which was enhanced further by the addition of sugar, oil or dry milk. The addition of as little as 0.10 percent of bacterial amylase to the dry mix greatly increased the calorie density (Jansen et al 1981). The product is precooked, meaning less use of home-cooking fuels.

#### **III.1.4 Roasting**

Roasting involves removal of moisture by dry heat treatment in an open pan. The starch gets partially gelatinised during the process and certain degree of dextrinisation takes place to yield a low viscosity product with enhanced flavour.

#### **III.1.5 Puffing**

Puffing is a process where the food grains are exposed to high temperature in a sand bath for a short period of time. The sudden evaporation of moisture of the grain makes it puff. The starch gets gelatinised and the product has a light, porous texture.

### III.1.6 Flaking

Flaking consists of parboiling of grains followed by pounding or pressing between rolls. The process of parboiling gelatinises the starch and yields a low viscosity product.

## III.2 Chemical methods

### III.2.1 Addition of enzyme :

Addition of heat resistant  $\alpha$ -amylase to the starch rich weaning food held at 150-160°F for about 4 minutes followed by agitation leads to conversion of starch into dextrans. This is at times followed by digestion with amyloglucosidase which converts maltose into glucose. The mixture is then drum dried which also inactivates the enzyme. The sugars produced impart a malt syrup flavour to the product and yield a smooth low viscosity product on reconstitution (Windish and Mhatre 1965 and Buffa 1971).

### III.2.2. Germination/Malting :

Germination and malting are age-old household level technologies, especially in Asia and Africa. Sprouted mung are widely consumed in South East Asia. Sprouted legumes are cooked into savoury preparations and are popular as vegetable substitutes in Indian diets. Flour from germinated finger-millet has traditionally been a popular weaning food in Southern and Western parts of India and has been successfully reintroduced in the form of cereal + pulse + oilseed malted multi-mix (Dearden et al 1980). Germination of sorghum (Kimea) for beer fermentation is practised in Africa and Kimea has been adopted now to

develop low bulk weaning foods (Mosha 1983). During the process of germination a wide array of enzymes particularly amylases are elaborated which breakdown the starch in the grain into dextrans. The flour from germinated cereals yields low viscosity gruels on cooling due to high solubility of the dextrans produced (Desikachar 1980).

Desikachar (1980) studied the effect of various heat processing technologies viz. puffing, flaking, toasting, extrusion and malting on the viscosity of the cereal + pulse + oilseed multimixes. Each of the processed samples had a lower viscosity than its raw counterpart. However, desirable viscosity reduction could be achieved only on addition of barley malt at 5% of total solids.

Of all the technologies discussed above roller and spray drying, extrusion cooking, puffing, flaking, roasting and addition of enzyme are strictly industrial technologies. Of these roller drying, spray drying and extrusion cooking call for inputs like sophisticated machinery, its maintenance etc. which certainly adds to the cost of the finished product. Therefore, germination or malting seems to be the appropriate technology for the development of low bulk weaning foods since it is the most effective and cheapest household level technology.

The terminologies viz. sprouting, malting and germination are often used interchangeably to describe the process of soaking or steeping the dry grains in water until they are saturated followed by germination under controlled conditions for a specific period. The term **malting** is used when grains

particularly barley, are soaked and germinated for brewing purposes.

The sprouting of grain legumes has been popular for centuries in the Orient (Salunkhe et al 1985). Many kinds of sprouts are now sold even in Western super markets. Increasing amounts are being consumed in raw or cooked forms (Kyllen and McCready 1975 and Watt 1974). However, sprouting of cereal grains for food purposes is of recent origin. The sprouting treatment to dry seeds is reported to improve their nutritional quality by increasing the contents and availability of essential nutrients and decreasing the levels of anti-nutrients (Chavan and Kadam 1989).

#### **III.2.2.1 Grains for sprouting :**

All the cereal grains that are consumed by man as a source of food viz. rice, wheat, corn, barley, sorghum, millets, oats and rye have been used for sprouting. Considerable variations in conditions employed for each grain is reported in order to achieve maximum yield of sprouts and nutritional benefits. The grains used for germination should be clear, sound, free from broken and infested seeds, untreated and viable. Several factors seem to influence the germination of seed and development of sprouts. They are as follows:

#### **III.2.2.2 Seed viability :**

The aliveness or ability of the seed to germinate under favourable conditions is called viability, and the degree of aliveness is referred to as vigor. The sound, healthy, untreated dry seeds of most cereals can retain this ability for

several years under storage conditions favouring low metabolic activity such as low temperature, low moisture and high carbon dioxide concentration (Mayer and Poljakoff-Mayber 1963).

Several factors are responsible for loss of seed viability during storage viz. seed moisture, relative humidity, temperature, concentration of gases and irradiation treatment. The physical condition of the seed, inheritance, microflora and insects and use of fungicides and pesticides also influence the seed viability. Seeds with higher moisture content stored at high temperature undergo rapid deterioration due to several cellular, biochemical and cytogenetical changes (Ghose et al 1981, Roberts 1973 and Ching and Schoolcraft 1968).

#### III.2.2.3 Water availability :

A viable dry seed requires water for the germinative process to begin. The water is imbibed by the seeds during soaking. The amount of water imbibed is influenced by seed size, seed coat permeability, quantity of available water and chemical composition of seeds. The larger seeds take a longer time than the smaller seeds to become saturated with water. The seed coat permeability depends on its structure and composition which vary between different cereals and also within cultivars of each cereal. Among the endosperm components, proteins are mainly responsible for water absorption. Hence, seeds containing higher protein are expected to imbibe more water during germination and sprout development (Chavan and Kadam 1989).

Water absorption takes place in 3 phases. Phase one covers first 6-10 hours of soaking period marked by a rapid water uptake of upto 60% of the total. This rapid uptake is generally attributed to water imbibition by the seed colloids, primary proteins and carbohydrates. In phase two, the following 10 to 20 hour period, water uptake is slow and starch is hydrolysed to sugar. The hydrolytic process produces osmotic pressure which results in the uptake of water by embryo which is found to be sufficiently moist and metabolically active. During phase three (over 20 hours), again there is a rapid uptake which is followed by a plateau. Steeping beyond this phase leads to a breakdown of the semipermeable membrane (Brooks et al 1976).

#### III.2.2.4 Temperature :

Temperature is a crucial factor to produce the highest percentage of germination in the shortest time. Most cereal seeds can germinate at a temperature range between 3 to 40°C. At very low or high temperatures, germination is usually prevented. The minimum, maximum and optimum temperature ranges in which germination occurs in most cereal grains are summarised in Table 3. Most cereal seeds require 20-30°C as the optimum temperature range for maximum germination at a faster rate. However, seeds like corn require near 35°C as the optimum temperature for germination (Edward 1932). At 20°C soyabean took about 10.5 hours to reach 90% of the total absorption. At 30°C this same level of absorption took approximately 6 hours and at 50°C it took only 2-5 hours (Hsu et al 1983).

**Table 3: Temperature ranges for sprouting of different cereals**

Temperature (°C)			
Cereal	Minimum	Optimum	Maximum
Barley	3-5	19-27	30-40
Corn	8-10	32-35	40-44
Rice	10-12	30-37	40-42
Rye	3-5	25-31	30-40
Wheat	3-5	15-31	30-43

**III.2.2.5 Atmospheric conditions :**

Most seeds germinate at the normal level of oxygen (20%) and carbon-di-oxide (0.03%) in the air (Mayer and Poljakoff-Mayber 1983). Increased germination can be expected in certain seeds if the oxygen concentration is increased. However, such a practice may not be feasible and economical particularly at the domestic level. The effect of carbon-di-oxide is the reverse of that of oxygen.

**III.2.2.6 Other factors :**

Cereal seeds germinate equally well under dark and light but may not be feasible and economical particularly for domestic conditions (Chavan and Kadam 1989). However, dark conditions may be more advantageous to avoid photosynthetic activity in developing sprouts.

### III.2.2.7 Methods for germination :

Different methods have been used to produce grain sprouts (Watt 1974, Harmon et al 1987). The dry seeds are soaked in water (1:3 w/v) until they are fully saturated. After soaking, the excess water is drained and the seeds are placed in a container or tied in cloth for sprouting in a warm place. At the domestic level, no special equipment is used. Any suitable kitchen container, such as plates, bowls, pans or simply tying the soaked seeds in a moist cloth has been used to sprout grains (Watt 1974 and Whyte 1973). Care is taken to allow proper rinsing and draining of the sprouting seeds for aeration and to avoid fungal growth. For more controlled sprouting of small quantities of grains at home, special jars or sprouters, trays, pails and frames have been suggested (Lorenz 1980, Hamad and Fields 1979, McConnel 1977).

For the production of large quantities of sprouts on a commercial scale, rotating jars on a device developed by Miller (1978) or a tight closet with steam or hot water heating pipes at the bottom and suitable trays for the thoroughly moistened grain are ideal (Bartlett 1917). The above equipment has been successfully used for germination of wheat and oats respectively.

The process of sprouting is affected by several factors. Best malt is produced from grains (barley) soaked for 15 hours having a moisture content of about 43-46% (Brooks et al 1976, Piendl 1971, Briggs et al 1981). Lukow and Bushuk (1984) have reported a steeping period of 16 hours in excess water at 4°C for optimum germination. A steeping period of one hour at 35°C and 25°C for pearl-millet and barley respectively has been reported as satisfactory (Sheorain and Wagle 1973). Optimum moisture content for effective germination in wheat

has been reported as 42% (Singh et al 1983). Table 4 summarises the conditions of germination and yield of sprouts for a few grains (Whyte 1973).

**Table 4 : Suggested sprouting temperature, time and yields of sprouts**

Cereal	Sprouting temperature (°F)	Sprouting time (days)	Frequency of water rinse (per day)	Yield cup (cups/dry grains)
Barley	70-80	3-4	2-3	2
Buck wheat	68-80	2-3	1	3
Corn	72-86	2-3	2-3	2
Millet	70-80	3-4	2-3	2
Oats	70-80	3-4	1	2
Rice	50-80	3-4	2-3	2-5
Rye	50-68	3-4	2-3	3-5
Wheat	70-80	3-4	2-3	3-5-4

### III.2.2.8 Biochemical changes during germination

The metabolic activity of resting dry seeds increases as soon as they are hydrated during soaking. Complex biochemical changes occur during hydration and subsequent sprouting in various parts of the seed.

### III.2.2.8.1 Changes in dry matter :

The original dry weight of seed decreases during soaking and subsequent sprouting process due to leaching of materials and oxidation of substances from the seed. The germination of wheat for 5 to 7 days resulted in a 17% loss in total carbon (McConnel 1977). The distribution of labelled carbon showed mobility of the constituents and movement from the seed to the sprout. The losses in dry matter to the extent of 20-25% in sprouting rice have been reported (Fukai and Nikumi 1956). On sprouting for 8 days, oats lost 17% dry weight (Bartlett 1917). Yocum (1925) observed a 25% loss in wheat seeds after 12 days of sprouting. Nielsen et al (1978) reported that the loss in dry matter during sprouting of wheat is influenced by cultivar, germination period and temperature. Significant loss occurred at 30°C between 4 and 7 days of sprouting. By the fourth day, the dry matter losses were 5 to 6% at 20°C and 10 to 16% at 30°C in three cultivars. Similar dry matter losses of wheat during sprouting were reported by Miller (1978). Pathirana et al (1983) observed about 3% weight loss in sorghum grains when steeped for 8 hours and germinated for 24 hours. However, the losses were found to increase up to 30% when the germination period was extended to 6 days. Bhise et al (1988) studied the influence of steeping and germination on dry matter loss in sorghum. With a 10 hour soaking, the dry matter loss increased from 3.2 to 19.5% during 3 days of sprouting. The loss in dry weight is due to increased metabolic activity of sprouting seeds. The energy required for the increased metabolic activity is derived by partial degradation and oxidation of starch, which is mainly responsible for the decrease in dry weight of the sprouted seeds.

The loss in dry weight during sprouting needs to be minimised. This can be achieved through certain chemical treatments to the seed. The seeds of corn and sorghum steeped in 0.3% ammonia showed higher water imbibition and prevented the formation of rootlet and acrospire which minimized dry matter loss (Khan et al 1977). A dry matter loss of 5% is non-significant which implies that most seeds need to be soaked for 8 to 10 hours and germinated for not more than 24 to 48 hours. In the grain legumes, maximum nutritional benefits were produced when the seeds were soaked for 10 hours and sprouted for 24 hours. An extended sprouting period has been found only to increase dry matter losses with non significant nutritional improvements (Ghorpade and Kadam 1990).

#### III.2.2.8.2 Changes in proteins :

Several investigators have reported the changes in total protein content in cereal grains (Muckle and Sterling 1971, Hamad and Fields 1979, Nielsen et al 1978, Bhis et al 1988, Pomeranz and Robbins 1971, Hwang and Bushuk 1973, Ranhotra et al 1977, Lemar and Swanson 1976). Some reports have indicated an increase while others have shown a decrease in protein content upon sprouting. Few reports also indicate non-significant differences in protein content due to sprouting of cereals. Total nitrogen was found to increase significantly in wheat after 7 to 10 days of germination (Nielsen et al 1978). Similar results were reported by Miller (1978). The sprouting of wheat for 4 to 5 days at 23°C or for 3 days at 30°C also produced increases in the total protein content (Ranhotra et al 1977, Lemar and Swanson 1976). Dalby and Tsai (1976) studied changes in the protein content in several cereal grains during 5 days of sprouting at 28°C in the dark. The total protein increased steadily with time of sprouting in wheat,

triticale, rye, barley, and rice and remained unaltered in oats. Similarly, Hamad and Fields (1979) observed an increase in protein content in wheat, barley, oats and rice after 5 days of sprouting at 20°C. The increase in protein content has been attributed to loss in dry weight, particularly carbohydrates through respiration during germination. Contradictory reports on protein content in sprouted seeds are also available. Hwang and Bushuk (1973) observed a small loss in protein of flour from wheat soaked at 10°C for 2 days followed by germination of upto 8 days. Soaking of sorghum beyond 10 hours followed by prolonged germination (beyond 3 days), caused a marked reduction in protein content (Bhise et al 1988). Such a decrease can be attributed to the loss of low molecular weight nitrogenous compounds during soaking and rinsing of grains.

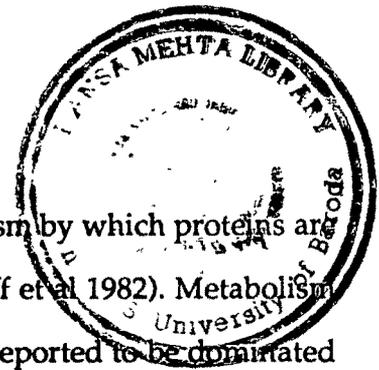
#### III.2.2.8.2.1 Changes in protein fractions :

The storage proteins of cereal seeds are classified as albumins (water soluble), globulins (salt soluble), prolamins (alcohol soluble), glutelins (acid or alkali soluble) and residue or insoluble proteins (Osborne and Mendel 1914 and Nagy et al 1941).

The storage proteins are partially hydrolysed by the proteolytic enzymes which is evidenced by an increase in water soluble proteins and free amino acids in sprouted seed meals.

Prolamins and glutelins form more than 80% of the total seed protein and are known to be deficient in lysine (Kent-Jones and Amos 1967, Salunkhe et al 1984).

Therefore, an increase in water soluble fractions indicates an improvement in the protein quality. In wheat the water soluble proteins were found to increase six-fold after 10 days of sprouting (Nielsen et al 1978, Pathirana et al 1983). Hwang and Bushuk (1973) however, observed a decrease in water soluble proteins when seeds of wheat were soaked at 10°C for 2 days prior to sprouting. Similarly Bhatta (1969) observed a decrease in soluble protein content of the barley grains after steeping until the second day of germination. This decrease is attributed to solubilization and leaching of proteins during prolonged steeping of grains and to in situ utilization of the soluble proteins by the germinating embryo during the early germination period when there is little proteolytic activity developed in the seed. Hwang and Bushuk (1973) studied the changes in various protein fractions of wheat during sprouting for 2 to 8 days. Both water and salt soluble proteins decreased while the proportions of the alcohol soluble proteins remained fairly unchanged and that of acid soluble fraction increased parallel with the decrease in the residue proteins during sprouting. The recovery of proteins also decreased with sprouting. The decrease in albumins and globulins has been attributed to leaching losses, while an increase in glutelin fraction is due to gradual degradation of the residue proteins. Tsai et al (1975) however, observed a very significant decrease in the alcohol soluble prolamin fraction in normal maize during 5 days of sprouting. The prolamin content was found to decrease in wheat, triticale, barley, rye and oats germinated for 5 days (Dalby and Tsai 1976). The variations in the results of Hwang and Bushuk (1973), and Tsai et al (1975) on changes in protein fractions of wheat due to sprouting can be attributed to the methods of sprouting and protein fractionation.



Attempts have been made to study the mechanism by which proteins are altered in germinating seeds (Riggs et al 1983, Fertzdorff et al 1982). Metabolism of amino acids and proteins in germinating barley was reported to be dominated by transformation of reserves stored in the embryo into protoplasmic protein and other nitrogenous constituents of the young embryo (Folker and Yenum 1958). Fertzdorff et al (1982) studied the malt modification in barley by histochemistry, light microscopy and transmission and scanning electron microscopy. It was observed that the hydrolysis of proteins was more extensive in the starchy endosperm area adjacent to the scutellar epithelium. The hydrolytic changes decreased as distance increased from the embryo end to the distal end, and from the aleurone layer to the centre of the starchy endosperm. The cell wall hydrolysis was found to be more extensive than protein and starch hydrolysis during malting. When sorghum is malted, much of the nitrogen in the kernel was found to be transferred to the roots and shoots (Taylor 1983). The prolamins, which are located mainly in and near aleurone cells, were the major source of the nitrogen transferred.

#### III.2.2.8.2.2 Changes in amino acids :

The changes in amino acids content during sprouting of cereal grains have been studied (Taylor 1983, Jones 1969, Smith 1972, Robbins and Pomeranz 1971). Tsai et al (1975) observed a large and rapid increase in lysine and tryptophan during a 5 day germination of normal corn. After 2 to 3 days, the levels of these amino acids were equivalent to those found in opaque 2 and flourey 2 variety. Wang and Fields (1978) sprouted corn and sorghum at 25, 30 and 35°C for 2 to 5 days and determined the increase in available lysine,

tryptophan and methionine. Folker and Yenum (1959) observed that, during 10 days of germination of barley at 22-5°C the lysine content increased by 65% over that in the ungerminated grain. The percentage increase in lysine was found directly proportional to grain protein content. Most of the lysine increase occurred in the embryo. Malleshi and Desikachar (1986) reported significant increases in lysine and tryptophan contents in pearl millet, finger millet and foxtail millet germinated for 48 hours. The mechanism of increase in lysine has been proposed. The degradation of prolamins into lower peptides and free amino acids supplies the amino groups. Glutamic acid and proline have been implicated in providing nitrogen. However, the sources of carbon skeleton for increased tryptophan synthesis need to be identified.

#### III.2.2.8.3 Changes in enzyme activities :

The enzymes present in dry seeds become active as the seeds imbibe water. During soaking and subsequent germination, activities of various enzymes significantly increase. However, the hydrolytic enzymes predominate during the early germination and sprouting process. These include carbohydrate degrading enzymes viz.  $\beta$  and  $\alpha$  amylases, endo  $\beta$  gluconase, limit dextrinase, protein hydrolyzing proteases and lipid-degrading lipases. Among the carbohydratases,  $\alpha$  amylase is the main starch hydrolyzing enzyme. The activity of amylases significantly increase during sprouting of cereal seeds (Pomeranz and Robbins 1971, Hwang and Bushuk 1973, Singh and Tauro 1977, Lorenz 1974, Pomeranz and Shands 1974, Malleshi and Desikachar 1979, Malleshi and Desikachar 1982 and Malleshi and Desikachar 1985).

The extent of increase in activity varies with the type of cereal grain variety, conditions of sprouting, and use of germination promoters or inhibitors during steeping and sprouting. Among cereal grains, barley seeds develop maximum  $\beta$  and  $\alpha$  amylases during malting. Hence barley is most preferred for commercial brewing. The maximum development of amylase activity usually occurs after 6 to 7 days in sorghum and wheat, after 4 days in corn and after 3 days in millet (Novellie 1962, Malleshi and Desikachar 1982). Corder and Henry (1989) studied the elaboration of carbohydrate degrading enzymes during the 5 days of germination of wheat.  $\alpha$ -amylase increased from the first day to reach a peak after four days.  $\beta(1-3)$  (1-4) glucanase increased from day one to day five. Endo (1-4)  $\beta$  xylanase activity increased only slowly until the fifth day when activity increased more than 3 fold.  $\beta$ -fructofuranosidase was not detected until the third day. The activity of all the enzymes declined when the grain was dried at 30°C but, the effect of drying varied,  $\alpha$ -amylase activity was reduced by 69%, whereas  $\beta$ -amylase activity declined by only 16%. Harinder and Bains (1987) studied the effect of salt and pH on  $\alpha$ -amylase activity by determining falling number and amylograph viscosity. Addition of salt was found to have an inhibitory effect on  $\alpha$ -amylase action. At pH 4.2 the liquifying action of  $\alpha$ -amylase was considerably retarded.

Kneen et al (1942) studied the influence of temperature on the development of amylases, changes in sprout length and in dry and green weight in germinating wheat. Changes taking place at the different temperatures were quite similar, differing essentially only on the rapidity of change. At the germination temperatures of 20°, 15°, 10°, 5° approximately 4, 6, 10 and 24 days respectively were required to produce equal levels of sprout length and amylase

activity. The green weight of the developing seedlings increased steadily throughout the germination period. On the other hand total dry weight showed some decrease which was most pronounced at 20°C germination temperature.

There is a significant increase in the proteolytic activity of grains during sprouting (Hwang and Bushuk 1973, Bhattu 1969, Aisien 1982). After 2 days of sprouting, wheat produced a relatively small increase in proteolytic activity (Hwang and Bushuk 1973). However, it rapidly increased 17 fold after 8 days of sprouting. In barley, the proteolytic activity was marginal during the first 2 days, increased to maximum thereafter on the fifth day, and remained constant till the ninth day of sprouting (Bhattu 1969). An increase in proteolytic activity during sprouting is desirable for nutritional improvement of cereals because it leads to hydrolysis of prolamins and the liberated amino acids such as glutamic acid and proline are converted to limiting amino acid such as lysine. Reports on the changes in proteolytic activity in other cereals is scanty. Wilson et al (1988) studied the proteases of soyabean. The results reported support those from previous studies where a general pattern of storage protein mobilisation that involves an initial limited specific proteolysis of the protein is observed. Only after this initial triggering cleavage does the protein become susceptible to further more extensive proteolysis by other proteases. Two different proteases K1 and G1 appear to be involved in initiating the proteolysis of two distinct proteins in the soyabean, the Kunitz-type trypsin inhibitor and glycinin. A similar situation has been observed in the mung bean, *Vigna radiata*, where the degradation of the major storage globulin, vicilin, is initiated by vicilin peptidohydrolases while the degradation of the Bowman-Birk type trypsin inhibitor is initiated by another distinct protease, proteinase F (Wilson and Al Tan-Wilson 1987).

Compared to carbohydrates and proteins the lipids are present in relatively small amounts in cereal grains. Hence, very few reports are available on changes in lipase during sprouting of cereals. Secondly they are of little significance in context of the present study.

#### **III.2.2.8.4 Changes in carbohydrates :**

An increase in the activities of amylases and maltase during sprouting causes a gradual decrease in starch with a concomitant increase in reducing and non-reducing sugars during sprouting of cereal grains (Mayer and Poljakoff-Mayber 1963, Bartlett 1917, Fukai and Nikumi 1956, Pathirana et al 1983, Bhis et al 1988, Dronzek et al 1972). The first starch component attacked by amylase in rice was shown to be amylopectin (Fukai and Nikumi 1956). Considerable increases in free sugars have also been reported during the sprouting of wheat and barley (Dronzek et al 1972, Lorenz 1974). Both soaking and sprouting periods have been found to influence the loss of starch and accumulation of sugars (Bhis et al 1988). The soaking of seeds for 10 hours improved the starch digestibility significantly. However, prolonged soaking and germination beyond 10 and 24 hours respectively caused adverse effects on the susceptibility of residual starch to  $\alpha$ -amylase. This indicates that a short soaking and sprouting period are advantageous over a prolonged sprouting treatment to seeds.

#### **III.2.2.8.5 Changes in lipid content :**

The lipid content was found to be higher in sprouts compared with unsprouted seeds of barley, wheat and oats (Yocum 1925, Bartlett 1917, Lin and Pomeranz 1976). The increase in fat content has been attributed to the synthesis of fats due to transformation of disappearing starch. The sprouting treatment has been found to decrease the fat content in sorghum. Lemar and Swanson (1976)

indicated that there were no differences in fatty acid composition between wheat sprouts and ungerminated wheat. The lipids of pearl millet grains are implicated in the decreased shelf life of its flour. Hence any beneficial qualitative changes in millet lipids during sprouting will be advantageous.

#### **III.2.2.8.6 Changes in mineral content :**

The malting of barley increased its ash content from 2-4 to 6-7.1%. Similar results are also reported for wheat (Ranhotra et al 1977, Lemar and Swanson 1976). The quantitative changes in an individual mineral element and its chemical form during sprouting may be more important than the changes in total ash. Malleshi and Desikachar (1986) found a decrease in calcium, total phosphorus and phytates and phytate phosphorus during 48 hours of sprouting in pearl millet, finger millet and foxtail millet. The decrease in phytates and phytate phosphorus is nutritionally desirable.

#### **III.2.2.8.7 Changes in vitamins :**

Lemar and Swanson (1976) reported higher values for thiamine and riboflavin in meal obtained from sprouted wheat than from unsprouted wheat. The wheat sprouts have been shown to be a rich source of the B-group of vitamins and also contain some provitamin A and vitamins D and E (Pomeranz and Robbins 1971).

#### **III.2.2.8.8 Changes in antinutritional factors :**

Polyphenols, phytic acid, tannins which are usually present in the testa layer of the seeds are known inhibitors of trypsin, chymotrypsin, amylases, cellulases and  $\beta$  galactosidases. In addition they bind with proteins and form

complexes thus making proteins unavailable. Detrimental effects of polyphenols and tannins on the availability of minerals and vitamins have been reported (Salunkhe et al 1990, Chavan et al 1981).

Sprouting of cereals has been reported to decrease the level of phytic acid and the tannin content in millets (Opuku et al 1981). Germination of high tannin sorghum for 24 hours decreased the content of assayable tannins by 29.4%. Such a reduction in tannin content can be increased upto 70.6% when the sprouting process is extended upto 72 hours (Chavan et al 1981). The rate of degradation of starch and accumulation of reducing sugars and free amino acids during a 5-days germination was markedly lower in a high tannin cultivar compared to the low tannin variety. Glennie (1983) observed that tannins in high-tannin sorghum formed complexes with proteins during malting, although tannins did not affect the germination percentage. These reports indicate that sprouting treatment does not decrease the tannin content of grain, but favours the formation of complexes between testa tannins and endosperm proteins.

### **III.2.2.9 Changes in cyanogenetic glycosides :**

#### **III.2.2.9.1 Their distribution in plant foodstuffs**

The cyanogenic glycosides are compounds that yield hydrogen cyanide (HCN) upon treatment with acid or appropriate hydrolytic enzymes. These compounds have a wide distribution among the higher plants, but they are also found in ferns, moths and insects. More than 1000 species of higher plants are reported to contain cyanogenic glycosides. These are built according to a uniform

structure from cyanhydrins or hydroxynitriles as aglycons to which a sugar moiety is attached by a glycosidic bond (Conn 1969 and Conn and Butler 1969). The first cyanogenetic glycoside, amygdalin was isolated in 1830 by Robiquet and Boultron-Charlard. Next described was linamarin in 1891 (Telek 1983). In search of the poisonous substance in sorghum vulgare, Dunstan and Henry in 1902 isolated dhurrin and obtained evidence which characterised the compound as p-hydroxymandelonitrile- $\beta$ -D-glucoside (Dunstan and Henry 1902). Since then not more than 20 other compounds have been characterised. Five amino acids valine, leucine, isoleucine, phenylalanine and tyrosine are the primary precursors of aglycons. The C-C=N moiety of these amino acids is incorporated intact into the cyanogenic glucosides as is depicted in Figure 4 (Conn and Butler 1969). The sugar component of the glycosides is a monosaccharide (usually glucose) or a disaccharide such as vicianose and gentiobiose. The carbon atom to which the glycosyl moiety is attached may be asymmetric and may provide the possibility of two diastereomeric forms yielding the same products on hydrolysis e.g. prunasin and sambunigrin, dhurrin and taxiphyllin (Conn 1969).

Table 5 lists the common cyanogenetic glycosides, some plants in which they occur, and the products formed on hydrolysis.

## Cyanogenic glycosides and their amino acid precursors

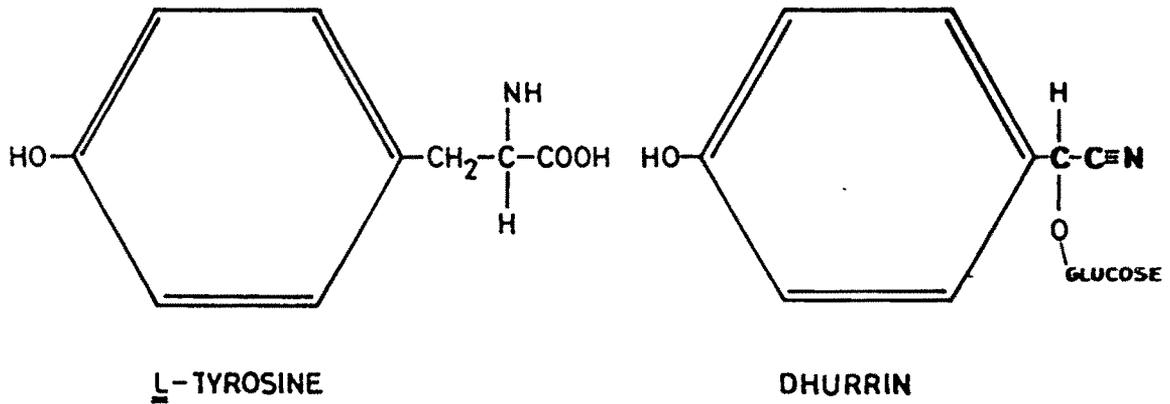


Figure: 4

**Table 5 : Commonly found cyanogenic glycosides their source and products of hydrolysis**

Glycoside	Plant source	Hydrolysis product
1. Amygdalin	Members of Rosaceae, including almond, apple, apricot, cherry, peach, pear, plum and quince.	Gentibiose + HCN + benzaldehyde
2. Prunasin	Members of Rosaceae including cherry, laurel, Eucalyptus cladocalyx, Linaria striata De	D-glucose + HCN + benzaldehyde
3. Sambunigrin	Sambucus nigra L (elder berry) Acacia sp (Australian acacias)	D-glucose + HCN + benzaldehyde
4. Vicianin	Vicia sp (common vetch)	Vicianose + HCN + benzaldehyde
5. Dhurrin	Sorghum sp (sorghums, Kaffir corns)	D-glucose + HCN + p-hydroxybenzaldehyde
6. Linamarin	Phaseolus lunatus L (lima bean, many varieties), linen flax, Manihot sp (Cassava or manioc) white clover, lotus sp	D-glucose + HCN + acetone
7. Lotaustralin	Occurs with linamarin	D-glucose + HCN + 2-butanone
8. Acacipetalin	Acacia sp (South African acacias)	D-glucose + dimethyl ketene cyanohydrin
9. Triglochinin	Triglochin maritimum L (arrow grass)	D-glucose + HCN + triglycochonic acid

(Source: Conn 1973)

Table 5 shows that there is no obvious pattern in the distribution of cyanogenetic glycosides in nature. It is also not possible to generalise regarding which parts of a cyanophoric plant contain the cyanogenic glycoside; they have been found in the roots, tubers, stems, leaves, flowers and seeds. Seeds of a cyanophoric species may not necessarily contain the glycoside, however. For example, sorghum seed with its high starch content can be safely consumed as food because it is lacking or very low in cyanogen. On germination, however, the dark grown sorghum seedling may reach a concentration of 0.3-0.5% HCN (dry weight) within a period of 3 or 4 days and the young green leaves are a rich source of dhurrin and only in the older plants does the concentration become low enough as to be non-toxic to humans (Conn and Butler 1969 and Panasiuk and Bills 1984).

The cyanogenic glycoside of sorghum dhurrin, has been extensively studied and reviewed (Conn 1969, 1978, 1979A, B, Eyjolfsson 1970, Nahrstedt 1973, Miller 1973, Tapper and Reay 1973 and Seigler 1975, 1976). It has been reported that the level of dhurrin in sorghum is influenced by many factors. Genetic variation was found by Collison (1919) and later this was confirmed by many others (Harrington 1966, Alvarado and Sylva 1967, Lloyd and Gray 1970, Gorz et al 1977 and Mcbee and Miller 1980).

In clover and trefoil two genes determining the cyanophoric nature of these species have been recognised. One gene is dominant for the production of the glycoside, while another controls the production of a  $\beta$ -glycosidase that hydrolyses the glycoside (Corkill 1942 and Jones 1966). The sorghum plant parts differ in dhurrin concentration, and the cyanide content decreases with age of the plant as previously mentioned. Wolf and Washko (1967) found that leaf blades

without midrib were high in cyanide in all growth stages, midrib, sheath and stem portions contained less with maturity. Decrease in HCN potential (HCN-p) of the entire plant was due to the proportional increase in weight of low cyanide containing parts. Benson et al (1969) studied the relationship of HCN-p of leaf samples to that of whole plants of sorghum and found that the small portions of various leaves could be used to compare varieties for HCN-p but that the leaf samples were not suitable for estimating the total amount of dhurrin in the whole plant. Lloyd and Gray (1970) studied the dhurrin content of various plant parts during the life cycle of three cultivars of high, medium and low HCN-p and also confirmed that the cyanide content of tillers, leaves, stems, heads and roots generally decreased with maturity. It has been reported that high nitrogen fertilisation increases the dhurrin content (Boyd et al 1938, Patel and Wright 1958 and Jung et al 1964). No correlation has been observed between the tannin content and HCN-p of sorghum (Dada and Dendy 1987). The extensive reviews on HCN content of sorghum are based primarily on studies on the sorghum seedling and the mature plant. Reviews pertaining to germinated sorghum are few. Germination of sorghum is known in several parts of Africa and Asia. Numerous investigators have proposed germination of cereals and sorghum in particular as one of the ways to improve cereal protein quality (Wang and Fields 1978, Pathirana et al 1983, Chavan et al 1981 and Lay and Fields 1981). However, the above studies have examined the change in protein and carbohydrates only. It was Panasiuk and Bills (1984) who reported the elaboration of HCN in germinating sorghum. The four cultivars of grain sorghum and four cultivars of sweet sorghum studied had traces (29 ppm) of HCN while the sprouts grown for 3 days from the same cultivars contained HCN which ranged from 258-1030 ppm. The average amount of HCN obtained (61.3 mg) from sprouts of

100 g of seeds was found to exceed the fatal dose for an adult (50-60 mg). However, recent work at Overseas Development Natural Resources Institute (ODNRI) has refuted the statement (Dada and Dendy 1987). Of the 19 varieties of sorghum studied, several were found to elaborate dangerously high levels of HCN on germination (74-643 ppm). Drying at 50°C of feterita sorghum (HCN content 454 ppm) was found to have little effect on HCN level. It was however found that when the germinated grains were toasted at 100°C or 180°C prior to drying at 50°C, the HCN level was lowered by 83 and 96.5% respectively. Fermentation of either a paste or a slurry of germinated sorghum for 24 hours resulted in a loss of HCN in excess of 70%. Boiling the slurry or steaming the paste eliminated the HCN completely. Frying or hot grilling the paste removed slightly more than 90% of the HCN. The HCN content in 'Kimea' added infant food was also studied. A maize porridge from 100 g maize meal to 400 ml water was prepared by boiling. The porridge was cooked for thirty seconds before adding in 10 g of 'Kimea' (germinated sorghum flour). Traces of HCN were detected in the hot porridge and that cooled to 60°C and 40°C. The authors have therefore recommended the addition of 'Kimea' at high temperature to ensure lowering of the HCN to safe levels.

#### III.2.2.9.2 Toxicity and detoxification of cyanogens and HCN

The knowledge of, manner in which cyanogenic glycosides give rise to HCN, permits one to understand the mode of toxicity by these substances. The action of two enzymes usually found in plants that contain cyanogenic glycosides is illustrated in Figure 5 for dhurrin a cyanogen occurring in sorghum. The initial reaction involves the hydrolysis by a  $\beta$ -glycosidase of the  $\beta$ -glycosidic bond between the sugar and the aglycon of the glycoside.  $\beta$ -glycosidases are

## Enzymatic decomposition of dhurrin to *p*-hydroxybenzaldehyde

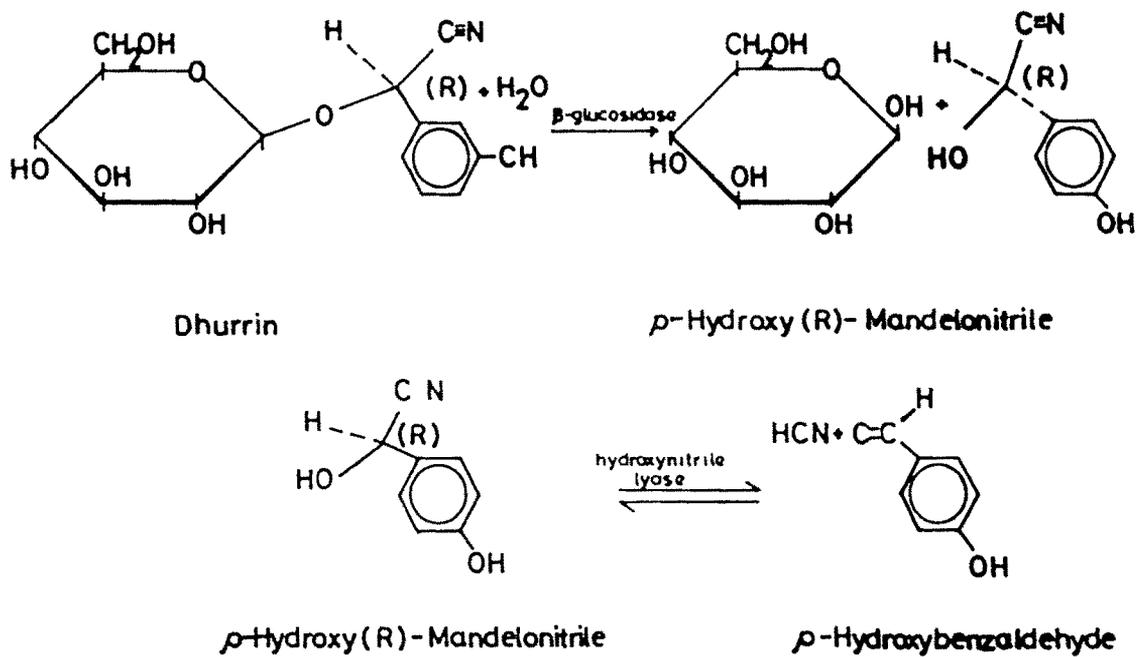


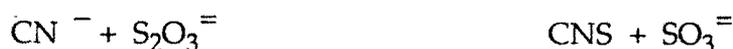
Figure : 5

highly specific for the  $\beta$ -glycosidic linkage that is characteristic of the cyanogenic glycosides (Conn 1973).

Although the  $\alpha$ -hydroxynitriles (cyanohydrins) produced by the action of plant glycosidases will dissociate non-enzymatically, hydroxynitrile lyases that catalyze the dissociation of these compounds are present in cyanophoric plants (Conn 1969). In the presence of the lyase, the cyanohydrin dissociates to produce HCN and the product ketone or aldehyde. The HCN is produced only after the disruption of the plant cells presumably due to the spatial separation of the enzyme from the cyanogenic glycoside in the intact cell. Moreover, little, if any, free HCN would be expected to accumulate in the cell since, being volatile it would escape to the atmosphere. From the above discussion it is clear why the ingestion of fresh cyanophoric plant material by livestock can result in the death of the animal. Maceration by the animal of the fresh plant tissue as it is ingested initiates the enzymatic breakdown of the glycoside by the plant enzymes described above. Therefore, the animal merely needs to eat enough of a plant that is sufficiently rich in cyanogen and enzymes to be poisoned. Most of the data on HCN poisoning cites loss to the livestock grazing on mountain mahogany choke berries, leaves of the eastern wild cherry, acacia and young sorghum plants (Kingsbury 1964, Hurst 1942 and Steyn and Rimington 1935). The HCN acts as a potent respiratory inhibitor. The site of inhibition is the enzyme cytochrome oxidase, the terminal respiratory catalyst of aerobic organisms leading to death. The occurrence of cyanogenic glycosides in plants (Table 5) that are commonly consumed by man as food can result in acute cyanide poisoning. In a review on the medical significance of cyanogenic glycosides in plants,

Montgomery (1965) has cited numerous references to the poisoning of humans by cassava and lima beans. Vichoever (1940) has documented several cases of poisoning by lima beans, a species that is widely distributed in the world and is one of the important staple and is consumed after scraping, grating, soaking in water and allowing it to ferment for several days which removes or hydrolyses the cyanogenic glycosides and destroys the  $\alpha$ -glycosidase. In a series of reports, Osuntokun and co-workers (1968, 1969 and 1970) have described evidence linking the degenerative disease known as tropical ataxic neuropathy to chronic cyanide intoxication of dietary origin. These papers implicate the high consumption of cassava in the disease in a group of Nigerians. The subjects exhibited an increased level of thiocyanate in plasma and an increased excretion of this compound in the urine. Similar findings have been reported based on controlled studies on hamsters (Frakes et al 1986).

HCN in non-fatal doses is metabolised by reaction with thiosulfate to form thiocyanate and sulfite as follows:



The thiocyanate excreted in urine confirms the presence of dietary HCN. While the conversion of cyanide to thiocyanate represents a detoxification process, thiocyanate in turn is a goitrogenic agent. Montgomery (1965) cites the cassava diet as a causative factor in tropical amblyopia which is common in West Africa and Bagchi and Ganguli (1943) report poisoning of cattle by sorghum in India. Similarly a diet of millet (sorghum) consumed by Senegalese may be responsible for a syndrome similar to ataxic neuropathy (Osontukun 1968).

Data on effect of processing on the HCN content is scanty. Dada and Dendy (1987) have reported, as mentioned previously total or partial destruction of cyanogenic glycosides on cooking while Panasiuk and Bills (1984) have refuted the same and reported the cyanogen namely linamarin to be relatively heat stable even at a temperature of 160°C. Gabel and Kruger (1920) reported that vomiting was produced experimentally in human subjects by cyanogenic lima beans which had been boiled for two and half hours and cyanide was detected in the urine. However, thorough cooking of foodstuff containing cyanogenic glycoside and discarding the cooking water eliminates the HCN to maximum possible extent (Montgomery 1969).

#### III.2.2.10 Changes in biological value :

The portion of food which gets digested and absorbed in the body is said to be biologically available. The portion that goes undigested passes on to the colon where it is acted upon by the colonic bacteria resulting into flatus (Brydon et al 1986). Therefore, of late bioavailable energy has been emphasised upon rather than the total energy especially, with respect to young child feeding (FAO/WHO/UNU 1985). Bioavailable energy is determined by the percentage digestibility of the food.

Of all the foods, legumes are known to have high levels of flatus factor. Although the raffinose family of sugars are held responsible for flatulence, there are reports on flatus production by starch and other complex non-starchy polysaccharides (El Faki et al 1983, Levitt et al 1987, King et al 1987). Poor digestibility of starch has been attributed to its chemical form viz. crystallinity, particle size and retrogradation of amylose fraction. Cooking of starch makes it less resistant to enzymolysis (King et al 1987).

Therefore, the effect of processing on the flatus producing factors especially in legumes has been studied extensively (Jood et al 1985, El Faki et al 1983, Boralkar and Reddy 1985).

Jood et al (1985) studied the effect of various treatments viz soaking in plain water and sodium bicarbonate solution, cooking of soaked seeds, autoclaving of soaked seeds, germination and frying of germinated seeds on oligosaccharide content and flatus production by Rajmah (*Phaseolus vulgaris*), Bengalgram (*Cicer arietinum*), blackgram (*Phaseolus mungo*), redgram (*Cajanus cajan*) and broad bean (*Vicia folea*). Soaking of seeds in plain water and sodium bicarbonate solution for 6 hours resulted in loss of oligosaccharides which increased on prolonging the soaking period to 12 hours and cooking of the soaked grains. Autoclaving resulted in further significant decrease in oligosaccharide content. Maximum reduction in oligosaccharides occurred during first 24 hours of sprouting. In addition it also resulted in better digestibility. Roasting for 10 minutes at 160°C resulted in improved in vitro starch digestibility of soyabeans. Soaking for 12 hours improved the starch digestibility further while germination was found to have maximum beneficial effect. Fermentation of soyabean batter was found to be equally effective as germination in improving the starch digestibility (Boralkar and Reddy 1985).

El Faki et al (1985) studied the flatus production in vitro and in vivo by the various fractions viz. oligosaccharides, starch, hemicellulose A and hemicellulose B from chick pea. The major gas produced was hydrogen. Highest gas was produced from hemicellulose followed by starch and oligosaccharides in vitro. The gas produced from the oligosaccharide fraction in vitro was significantly higher than that produced from starch and hemicelluloses.

The improvement in protein quality has also been studied in vivo and in vitro (Bartlett 1917, Ranhotra et al 1977, Dalby and Tsai 1986, Ram et al 1979, Malleshi and Desikachar 1986). Ram et al (1979) observed a slight but distinct improvement in biological value, net protein utilisation and utilizable nitrogen of corn after sprouting for 24 hours in rat feeding trials. Similarly, Malleshi and Desikachar (1986) found a significant improvement in PER of finger millet and fox-tail millet upon 48 hour sprouting in rat bioassay studies. A non significant improvement in PER of sprouted pearl millet proteins was observed. On the basis of changes in proximate composition, increased contents of certain essential amino acids and B group vitamins, partial degradation of proteins and starch, improved PER and biological value, it can be stated that sprouting improves the nutritive value of cereals.

#### **IV Development of supplementary foods**

Supplementary foods can be produced (i) at village, community or home level or (ii) centrally. In the first case, mothers have to be taught how to prepare weaning foods from locally available cereals and legumes. Mothers may prepare the foods in the home or in a group setting in a village.

Centrally processed weaning foods using appropriate technology (described in Section III.1 and III.2) also can make major contributions to reducing malnutrition. Such foods have a number of advantages in this context:

- (1) The use of precooked blends is energy efficient, particularly where fire wood is scarce and cooking is done over an open fire.

- (2) Processing can effectively inactivate antigrowth factors present in most legumes.
- (3) By virtue of protein complementation, processed blends of cereals and legumes have been demonstrated to be of high protein quality and well digested.
- (4) Processing can increase the caloric and nutritive density of gruels made from the blends.
- (5) As part of the central processing system, the blends can be easily and cheaply fortified with a broad range of vitamins and minerals.
- (6) Central processing facilities allow the use of suitable packaging to protect the nutritious products.
- (7) With suitable packaging, increased shelf life of the products results from reduced water activity and by inactivated hydrolytic, lipolytic and oxidative enzymes.
- (8) Central processing allows consistency of formulation and product quality.
- (9) Time saving to a busy mother, especially one with other responsibilities in addition to child care, results from the use of a precooked weaning food that requires only the addition of water at boiling point or safe drinking water.

Table 6 enlists some of the weaning foods developed in various countries:

**Table 6 : Weaning food formulations developed in various countries**

Product	Country	Primary ingredients
1) Balanced malt food	India (CFTRI)	Cereal, malt, pulses and skim milk powder
2) Bal-ahar (dry blend)	India (FCI formulated by CFTRI)	Wheat flour, groundnut flour, Bengalgram flour or skim milk powder
3) Flakes (Macaroni process)	India (CFTRI)	Edible groundnut cake flour, Bengalgram flour, greengram flour, wheat flour
4) Precooked weaning food of different formulae (Roller dried)	India (CFTRI)	Cereal flours, pulses and oilseed cakes
5) Bal-amul and Bal-amul cereal with milk (Roller dried)	India (NDDDB formulated by CFTRI)	Cereal flours, pulses, soya flour, skim milk powder
6) Nestum	India	Soyabean flour, milk powder,
7) Farex	India (Glaxo)	Cereals and milk powder
8) Lactogen	India (Nestle's product)	Wheat flour, milk

Product	Country	Primary ingredients
9) Incaparina	Columbia	Maize flour, cottonseed flour, soyabean flour, vitamin A, calcium carbonate
10) Pronutro	S Africa	Maize flour, soya, groundnut, wheat germ, skim milk powder, fish flour
11) Corn soya milk	U S A	Precooked maize, defatted soya flour, skim milk powder, CaCO <sub>3</sub> , vitamins
12) Caplapro	U S A	De-germinated maize flour, wheat flour, soya flour, skim milk powder, CaCO <sub>3</sub> , vitamins
13) Superamine	Algeria and Turkey	Hard wheat flour, chick-pea lentil flour, skim milk powder, vitamins
14) Faffa	Ethiopia	Wheat flour, field pea flour, skim milk powder, chick-pea lentil
15) Duryea	Columbia	Defatted soya flour, high lysine corn flour, corn starch, milk powder, vitamins, minerals
16) Peruvita	Peru	Cottonseed flour, Quinoa flour, skim milk powder, sugar, spices, vitamins
17) Laubina	Beirut	Wheat, chick-pea and skim milk powder

However, the centrally produced foods are expensive. Table 7 provides the comparative cost of weaning foods produced using various technologies.

**Table 7 : A comparative estimate of some of the processes used for the manufacture of weaning foods**

Process	Capital cost/MT* (US \$ x 10 <sup>-3</sup> )	Operating cost (US \$/MT)
Low cost extrusion	200 - 250	125 - 200
Drum drier	400 - 500	300 - 500
Spray drier	400 - 500	300 - 500
Baked goods	150 - 250	200 - 300
Fluid products	80 - 150	150 - 250
Milling	75 - 125	50 - 125

\* MT = Metric Tonne

Due to their high cost these foods are beyond the economic reach of the majority of the population. Therefore, the less expensive alternatives namely home/community level processing were sought in order to develop balanced, nutritious weaning foods.

Home level supplementary food processing has several advantages:

- (1) Locally available materials are used hence it is culturally acceptable.
- (2) Transportation cost is reduced thus making the product less expensive.
- (3) Minimises packaging costs.
- (4) Shortens storage time thus enhancing flavour and nutrient stability.
- (5) Promotes local employment opportunities.

Low cost multimixes have been formulated in different countries with adequate protein, fat and good acceptability among the target population (Gopaldas et al 1975, Tontisirin et al 1981, Devdas et al 1984, Romon et al 1987). In India 87-90% of the mothers prepare no special foods for their children. The adult diet is modified by mashing, soaking, chewing etc and fed to the young children (Venkatachalam et al 1967, Devdas et al 1984). Therefore, it is important to develop indigenous multimixes using locally available low cost foods and simple and familiar technology. Table 8 represents data on indigenous weaning food formulations.

**Table 8 : Indigenous weaning mixes**

Reference	Product	Ingredients
1) Pasricha et al (1973)T	Ready to mix powder	Cereal (wheat, pearl-millet or finger millet), pulse (roasted Bengal-gram)
2) Devadas et al (1974)	Weaning mix	Cereal (sorghum, finger millet, maize), pulse (roasted green or Bengal-gram), oilseed (roasted groundnuts) and jaggery
3) Gopaldas et al (1975)	Poshak	Cereal (wheat, maize, rice, or sorghum), pulse (Bengalgram or greengram dhal), groundnut and jaggery in the ratio of 4 : 2 : 1 : 2.
4) Gopaldas et al (1975)	Poshak (b) least cost weaning mix	Same ingredients as above in the ratio of 60 : 17 : 14 : 9
5) Rau et al (1975)	Extruded RTE	Corn soya milk and salad oil
6) Chandrasekhar et al (1976)	Kerala indigenous food	Tapioca rava, Soya Fortified Bulgar Wheat (SFBW), rava and groundnut flour
7) Indian Council of Medical Research (ICMR) (1977)	Ready to consume mixture	Roasted cereal (sorghum, maize, finger millet or pearl millet), pulse (roasted or sprouted Bengalgram), oilseed (groundnut/seasame cake)

All the multimixes developed are cereal based however, no alternative technology has been applied to lower the dietary bulk.

#### IV.1 Development of low bulk weaning foods

Of the several criteria laid down for the development of weaning foods an important recent addition has been with respect to the energy density (FAO/WHO/UNO 1985).

Hofvänder and Underwood (1987) have laid emphasis upon the energy density of the weaning foods as one of the nutritional considerations in the formulation of supplementary foods.

Buffa (1977) suggested the use of technology to improve and industrialise the production of traditional weaning foods and to render them economically accessible to the starving masses.

The use of following raw materials is suggested:

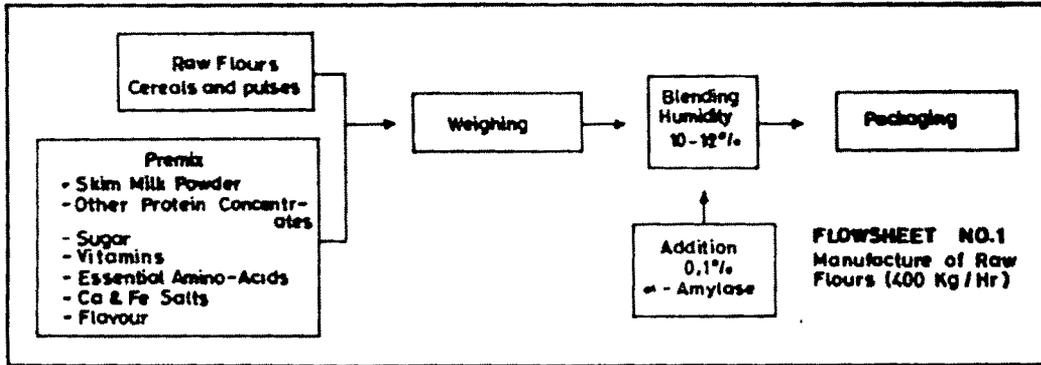
Cereals .. wheat, hard wheat, millet, rice, maize, sorghum

Pulses .. chick-peas, beans, peas, lentils, broad beans etc.

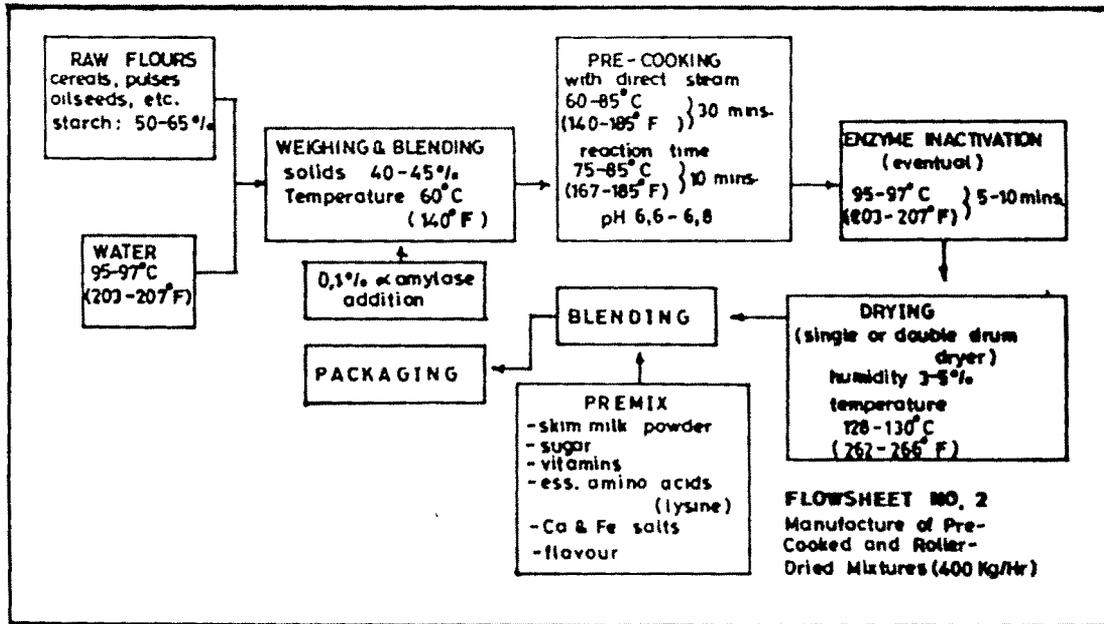
Oilseeds .. soya, sunflower etc.

The formulae can be obtained through computer programming after feeding all the constraints. The obtained formulae can be developed into the following products:

- (A) Raw multimix with high temperature resistant  $\alpha$ -amylase. This product must be home cooked for two or three minutes during which time the enzymatic action transforms 10 to 15% of the starch into dextrans, thus improving the digestibility of the product and remarkably reducing its viscosity (Figure 6 Flow sheet 1).
- (B) Precooked and Roller dried flours where the mixture of flours is diluted with water and roller dried at temperature of 130°C - 150°C. The finished product is in flake form and has a pleasant taste and smell. Due to the addition of  $\alpha$ -amylase the starch is converted into dextrans. The product therefore has a high solubility (Figure 6 Flow sheet 2). The manufacturing cost, and therefore the amortization are reduced by the enzyme treatment which enables the output to be doubled by diminishing the dilution and consequently the steam consumption by almost half. However, the technology is not polyvalent which keeps the cost considerably high.
- (C) Precooking and drying of flours following a new process has been developed. The pasta manufacturing line can be adapted to produce protein-rich pastas. Extrusion of the flour mixture containing 0.1%  $\alpha$ -amylase and water (68-70% solids) is carried out at a high temperature. A conversion time of 60 minutes is allowed when the heat resistant enzyme converts 50-70% of the starch. The carbohydrates of the flour mixture have a high digestibility and the viscosity of the resultant product falls to



SOURCE . BUFFA A.(1971)  
Fig.



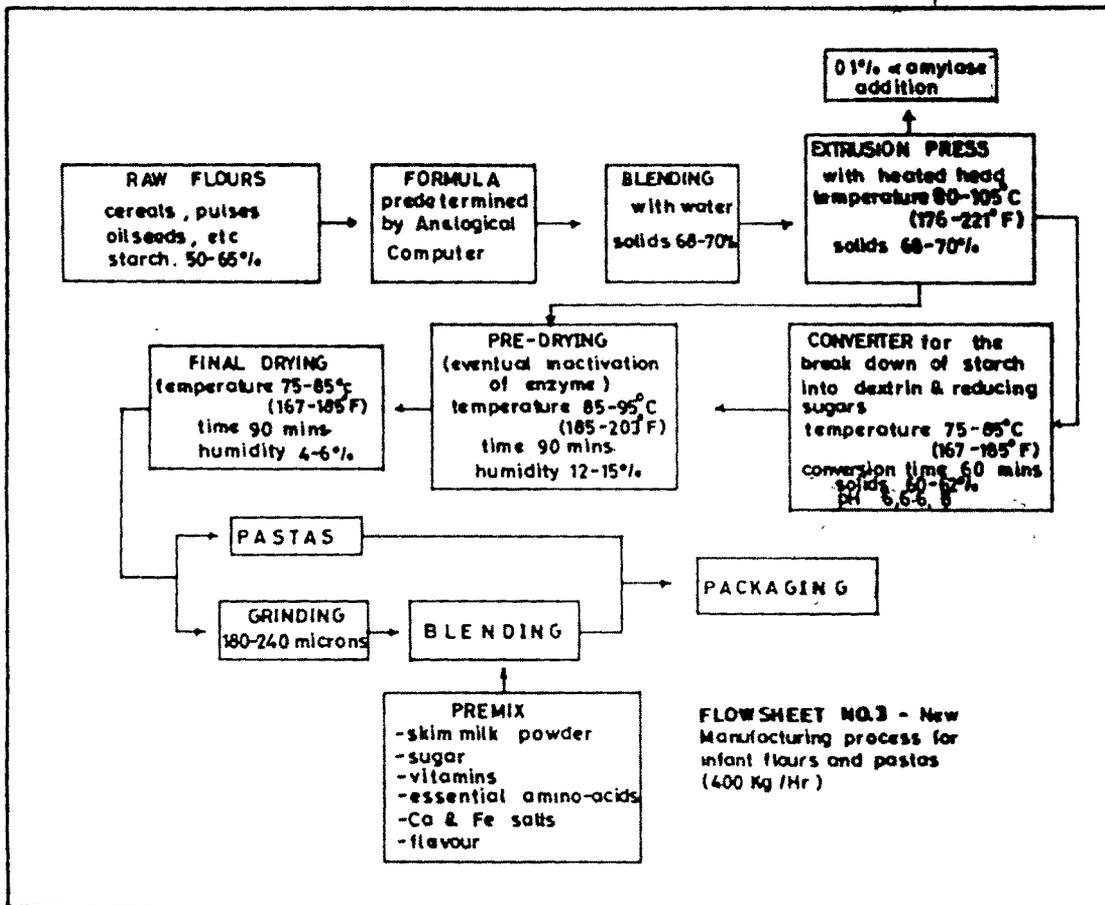
SOURCE: BUFFA A. (1971)  
Fig. 6

0.5% - 0.2% of the original level (Figure 7 Flow sheet 3). The method is polyvalent and reduces the cost of production and amortization.

A considerable effort has been made to develop low cost extrusion technology. Harper and Jansen (1985) after a comparative study of the various technologies concluded that the food extruder was an appropriate system for the control processing of nutritious foods.

Simple extruders, originally designed for cooking soyabeans on the farm have been adapted effectively for the purpose and are called low-cost extrusion cookers (LECs).

Extruded mixtures were reconstituted by adding required amount of boiling water (instant type) or boiled for 10 minutes by adding the required amount of water (cooking type). A viscosity of gruel deemed suitable by experienced mothers for feeding infants was established using Gerber cereal mix as a standard which had a viscosity of 1600 Cps. Plots of viscosity versus concentration of cereal gruels were made to determine the concentrations that produced this reference viscosity. The calorie density was also calculated. Table 9 summarises the results. The differences in calorie densities of gruels made from extruded as contrasted with raw cereal were greater when the 'cooking' procedure was used. When pretreated in dry form with 0.07% Rhozyme H 39, CSB extruded at 149°C gave a cooked gruel with a caloric density of 80.1 Kcal/100 ml compared to 64.5 Kcal/100 ml for the non-enzyme treated CSB.



SOURCE: BUFFA A. (1979)

Fig.7

**Table 9 : Effect of extrusion on calorie densities of cereal gruels of uniform consistency**

Sample	`Instant gruel'		`Cooked gruel'	
	g cereal product/ 100 ml	Kcal/ 100 ml	g cereal product/ 100 ml	Kcal/ 100 ml
CSB, raw	39.5	153.7	11.1	43.3
CSB, extruded 149°C	20.9	84.4	16.0	64.5
CSB, extruded 149°C + 15% NFDM	23.5	91.6	20.0	77.9
CSB, extruded 149°C + 4% Soya oil	20.0	84.4	18.0	76.2
CSB, extruded 149°C + 10% Sugar	21.5	86.1	18.2	72.9
CSB, extruded 149°C + 0.01% Rhozyme	30.6	123.6	19.8	80.1
CSB, extruded 171°C	18.7	76.0	18.5	75.2
CSB, extruded 171°C + 15% NFDM	21.7	84.6	21.8	84.8
CSB, extruded 171°C + 4% soya oil	19.9	84.9	19.3	82.2
CSB, extruded 171°C + 10% sugar	20.4	82.9	21.5	87.3
Title II CSM	32.0	121.6	14.8	56.1
Title II ICSM	22.1	84.1	13.4	51.0
Corn-raw	40.7	149.4	8.3	30.3
Corn, extruded 149°C	16.3	62.2	15.9	60.6
Corn, extruded 171°C	15.8	1.2	16.3	63.0
Gerber's mixed cereal	16.8	62.5	15.9	59.1

Malleshi et al (1989) developed a weaning food formulation based on malting and roller drying of sorghum (70%) and cowpea (30%). The cooked paste viscosity of malted weaning food was considerably lower than the roller dried preparation and the raw blend. The protein content of malted and roller dried preparation was 13.4% and 13.0% respectively. The protein efficiency ratio for malted weaning food (2.28) was significantly higher than that for the roller dried food (1.87).

Badi et al (1990) developed a drum dried baby food from the local staples viz. sorghum and millet. Milk powder was added to improve the protein quality and content. The viscosity was lowered by germinating a part of the sorghum/millet. The solids content could be increased keeping the viscosity low.

Hellstrom et al (1981) examined the various factors viz. addition of fat, starch, proteins, salt, pH and the effect of processing viz. extrusion cooking on the viscosity of wheat based protein rich supplementary food SEF. Of all the factors studied fat was found to lower the dietary bulk considerably. Starch, protein, salt and extrusion contributed to the dietary bulk while the pH during normal cooking conditions (5-7) had no impact on the dietary bulk.

Several cereal + legume based weaning mixes adapting malting technology have been developed. Extensive work has been done in this area which broadly falls into the following categories:

- (1) Fully malted mixes
- (2) Partially malted mixes
- (3) Amylase-Rich Food (ARF) technology.

#### IV.1.1 Fully malted mixes

Marero et al (1988) developed weaning food formulations from blends of 70 parts of germinated rice/corn and 30 parts by weight of germinated mung bean/cowpea. The formulations that yielded 3000 Cps viscosity in ungerminated and germinated flour blends contained only 0.81 and 1.3 g protein per 100 ml gruel respectively. The calorie content of the ungerminated blends was almost trebled when the germinated flours were used. The increase in nutrient density of rice formulations was higher than the corn formulations. Germination increased the essential amino acids, vitamins and minerals. The quality of Nigerian weaning food was improved by replacing part of the sorghum with cowpeas. The nutritive quality of maize, germinated and ungerminated cowpea mixture was studied against a commercial weaning food as a standard. The formulation with germinated cowpea had a better protein quality (Abbey and Mark-Balm 1988). Contradictory to the above Nathers et al (1987) found no improvement in the protein quality of multimix from germinated wheat, millet, garbanzo bean, mung bean and sesame. An improvement in mineral bioavailability is suggested.

In India ragi (*Eleusine coracana*) and pearl millet have been sprouted and dried to be used in the form of supplementary food for the weaning child (Rajalakshmi 1974). Brandtzaeg et al (1981) tried to reintroduce this technology by first carrying out extensive studies on malted multimixes from ragi, sorghum and green gram

A steeping time of 12 hours and germination time of 30 and 48 hours was required for ragi and sorghum respectively. Malting of green gram had minimal

effect on viscosity. The 25% gruel from ragi showed 100% reduction in viscosity while that from sorghum showed 150% reduction. The chemical and biological data support the beneficial effects of malting.

Malleshhi and Desikachar (1981) developed a malted weaning mix from ragi and greengram (70:30). Reduction in paste viscosity increased with progressive germination. The fall in viscosity was higher in ragi than greengram at a comparable slurry concentration. The malted weaning foods at all concentrations had considerably less viscosity than proprietary weaning foods indicating the highly beneficial effect of malting.

Malleshhi et al (1986) also explored the possibility of using other simple household techniques like popping, flaking, chapati/roti making, vermicelli extrusion for making weaning foods at the household level. Chapati like product was prepared from wheat, maize and sorghum in combination with greengram and Bengalgram. The extruded product was prepared from sorghum, greengram and Bengalgram and constituted the popped product while rice and soyabean was used for the preparation of the flaked food. The raw ingredients as well as the processing treatment influenced the cooked paste viscosity. The flaked product had a low viscosity (1700 Cp units). Chapati food prepared from wheat had the highest viscosity (6000 Cp units) followed by that from sorghum (3800 Cp units) and maize (2000 Cp units). The foods had a PER of 2-6 to 2-8 as against 3.2 for the skim milk powder and were well accepted by young children.

In the University Department of Foods and Nutrition, M S University of Baroda, Gujral (1968) formulated a cereal pulse conjee mix from sprouted wheat and greengram, roasted, ground and mixed in ratio of 4:1. Mothers were

supplied the dry mix and encouraged to cook it with jaggery and feed to the children. Supplementation studies conducted on pre-school children pair matched for age, sex, nutritional status and dietary intake for a period of eight months showed a marked improvement in their height, weight and nutritional status.

Fully malted mixes using wheat, Bengalgram and groundnut in the proportion of 4 : 1 : 1, 8 : 1 : 1, 4 : 1 : 0 were formulated by Gopaldas et al (1982) and by Tajuddin (1981) using ragi, greengram and groundnut in the proportion of 4:1:1. Master (1981) used wheat, Bengalgram and groundnut or gingelly seeds to formulate fully malted mixes. Fully malted mixes are characterized by a low hot paste viscosity and a high energy density and are the most appropriate for feeding of young children. However, the process requires a lot of time, space and other resources and lowers the feasibility of adoption by women from low income group. Partially malted mixes however are devoid of these drawbacks.

#### **IV.1.2 Partially malted ready-to-eat mixes**

Very little work has been done to develop partially malted mixes. An autoclaved mixture of 150 g sprouted, dried and powdered gram flour, 100 g of peeled mashed bananas and 70 g of jaggery was well accepted by children (Gopalan 1951). Korula (1961) formulated malt foods based on blends of ragi malt, low fat groundnut flour, Bengalgram flour, soyabean flour and sesame flour.

A partially malted food has been developed by Central Food and Technological Research Institute (CFTRI), Mysore. It is a cereal-based protein

enriched food containing blends of 40% malted sorghum, 40% low fat groundnut flour, 10% Bengalgram flour and 10% skim milk powder.

However, even the partially malted mixes were not fully devoid of the constraints of labour, time and space.

#### **IV.1.3 Development and use of Amylase Rich Food**

Malleshi and Desikachar (1982) reported the beneficial effect of addition of barley malt at as little as 5% solids level to the proprietary weaning foods on the reduction in viscosity on reconstitution.

Similarly Mosha and Svanberg (1983) studied the viscosity reduction on addition of germinated sorghum which is traditionally utilised for brewing beer. Incorporation of germinated sorghum at 5% solids level, in a cooked gruel of 15% solid content held at 40°C, rendered it semi-liquid.

These preliminary observations proved as important guidelines in the development of the amylase-rich-food (ARF) technology. With the chief purpose of obtaining a concentrated source of amylase from the staples consumed in various parts of India, research work was carried out in the University Department of Foods and Nutrition in this area from 1985 onwards.

Gopaldas et al (1986) developed an Amylase-Rich cereal malt from pearl millet. The study showed that this malt was required at 4% dry matter level for effective viscosity reduction of a 10% rice slurry. The germinated grains were dried by roasting at 70-80°C which resulted in a significant loss of the amylase content. The subsequent studies employed drying at low temperature viz. sun

drying ( $40\pm 2^{\circ}\text{C}$ ) and oven drying ( $50\pm 1^{\circ}\text{C}$ ) to obtain an ARF with high amylase activity from sorghum, maize, wheat, Bunti (*Echinochloa stagnina*) and Kodri (*Paspalum scorbiculatum*) (Gopaldas 1987, Gopaldas et al 1988, Patel 1988, Raj 1989). The shelf life of the ARF under ambient conditions of storage was studied. The amount of ARF required for desirable thinning of slurries of highest possible solid content was determined.

The ARFs were required in a catalytic amount of 4% of total solids for the effective thinning of slurries of 20% solid content. All the ARFs were found to be equally effective in reducing the bulk of traditional porridges, mashed bread, chapati, khichadi, biscuits, Soya Fortified Bulgar Wheat and very high starch foods viz. sago. Addition of jaggery and fat improved the calorie density and acceptability as judged by the mother-child dyad. Most importantly controlled intake trials were conducted among children 6-24 months of age which established a significantly higher intake of the energy-rich yet thin gruel (Gopaldas and John 1992, John and Gopaldas 1993). Germination is a familiar technology in Southern and Eastern Africa besides fermentation. Extensive efforts are being made to educate and encourage mothers to utilize this technology to improve young child feeding. Power flour has been developed from sorghum, the main staple of the region and utilised for making low bulk gruels (Svanberg 1988, Mosha and Lorri 1988, Lukmanji 1988, Kingamkono 1988, Luhila and Chipulu 1988). Table 10 provides data from various studies on effect of reduction in viscosity on food intake per meal and volume required to meet 60% of daily energy.

**Table 10 : Effect of reduction in bulk on food intake per meal and number of meals required to meet 60% of energy requirements in children 1 year of age**

	% dry matter	Intake per meal	Volume to supply 60% of energy requirements <sup>1</sup>	No. of meals required
Sorghum gruel <sup>2</sup>	8	350 <sup>e</sup>	2500	7-7.5
Sorghum gruel <sup>2</sup> + 5% sorghum Power flour	17	350	1200	3-3.5
Sorghum gruel <sup>3</sup>	20	277 <sup>a</sup>	870	3.1
Sorghum gruel <sup>3</sup> + 5% sorghum power flour	20	347	870	2-2.5
Barley gruel <sup>4</sup>	16	250 <sup>e</sup>	1000	4
Barley gruel <sup>4</sup> + 1% barley ARF	23	250	720	2.9
Wheat gruel <sup>5</sup>	20	31 <sup>a</sup>	429	14
Wheat gruel <sup>5</sup> + 4% wheat ARF	20	123	429	3

a - actual intake figures.

e - estimated intake figures.

Source : 1. FAO/WHO (1973)  
2. Mosha and Svanberg (1983)  
3. Svanberg (1988)  
4. Hansen et al (1989)  
5. Gopaldas et al (1990)

John and Gopaldas (1993) have also shown the effect of improved intake of low viscosity gruels on accelerated growth in children during a six months feeding trial. Significantly higher increments in weight and height of subjects fed low bulk gruel was observed.

The Amylase-Rich Food (ARF) has several advantages viz. it is low cost, it is required in small amounts and is based on a familiar technology hence mothers can prepare it at home. It can be added to a variety of foods while they are hot (70°C) and semisolid thus ruling out the need to prepare special foods for children. These attributes have earned ARF wider acceptability among rural/slum mothers (Gopaldas et al 1991) The simplicity and versatility of the technology has inspired other groups to carry out work on similar lines using cereals peculiar to their region.

Monsen et al (1989) reported the development of low bulk gruels using barley ARF. Gruels with comparable consistency from ungerminated barley and those with barley ARF at 1% dry matter level had an energy density of 0.65 Kcal/g and 0.90 Kcal/g respectively.

From the above review it emerges that utilisation of ARF technology is the most simple and cost effective technique to lower the dietary bulk and plug the food gap in the weanling's diet of LIG families in the developing world.