REVIEW OF LITERATURE

A conceptual framework for the study based on the ideas and concepts gathered from review work of existing literature of both theoretical and empirical nature will facilitate planning the study in a comprehensive manner. It also helps to know the previous research work carried out in the area and acts as a torch for new research.

2.1 Sorghum: Production, Utilisation and Nutritional Profile

Sorghum is consumed in various forms around the world like baked bread, porridge, tortillas, gruels, steam-cooked products etc. It has a potential to be processed into starch, grits and flakes. It can also be malted and processed into malted foods and beverages. On account of its nutritional significance and its easy adaptability to a wide range of growing conditions and lesser water requirements, sorghum has a potential to be incorporated in diets of human population around the world (Brannan et al., 2001).

In many parts of the world, sorghum has been traditionally used in food products and various food items like porridge, unleavened bread, cookies, cakes and malted beverages. It is also an important animal feed used in countries like the U. S., Mexico, South America and Australia. In the U.S., the white sorghum products are used to a small extent as a substitute for wheat in products for people allergic to wheat gluten (Fenster, 2003).

It is estimated that more than 300 million people from the developing countries essentially rely on sorghum as a source of energy. In Africa, sorghum-based thin porridge is prepared for fasting, sick or convalescent people, nursing mothers and as a complementary food for infants (Muhammad, 2004).

India is a major producer of sorghum and other millets. Sorghum and pearl millet account for nearly 5 percent (each) of the total cropped area, but this area is concentrated primarily in the arid and semi-arid regions of India, with nearly 60 percent of the rural population (ICAR, 2006).
It is a plant that is very economical to grow in dry areas with a high yield. Sorghum contains adequate nutritional values with 83% carbohydrate, 10% protein and 3.5% fat, however, sorghum also contains anti-nutrition compounds such as tannin and phytic acid which affects the human digestive system (Suarni, 2004; Elefatio et al., 2005).

Asfaw et al. (2005), stated that sorghum is an important food crop in the semi-arid regions of Ethiopia, because it is less dependent on rainfall, and therefore, less affected by fluctuations in environmental conditions. Still there is a need to increase its production and adoption both in domestic and industrial technologies for bread and infant foods.

According to Dicko et al. (2006), the protein content in whole sorghum grain is in the range of 7 to 15%. Starch is the main component of sorghum grain, followed by proteins, non-starch polysaccharides (NSP) and fat. The average energetic value of whole sorghum grain flour is 356 kcal/100g.

Sorghum is the fifth most cultivated and consumed grain in the world after wheat, rice, maize and barley (FAOSTAT, 2012). It is one of the crops that provide more than 85 percent of the world’s food calories. The production of sorghum in the year 2012 was 601 MT. In India, the crop is mainly produced in Maharashtra, Karnataka and Andhra Pradesh. Madhya Pradesh, Gujarat and Rajasthan are other sorghum producing states. Sorghum belongs together with millet to the small-grain cereals.

Sorghum probably originated in North Africa and spread throughout Africa and the Middle East and later on to China and America.

Sorghum grains are hard, and the outer bran layer is bitter and astringent and has to be removed by milling. In traditional home processing, sorghum is soaked prior to removal of the bran. Sorghum is used, similar to millet, for the preparation of gruels, weaning foods, porridge or unleavened bread. Porridge and gruels are also prepared with fermented sorghum. The color of sorghum grains may be white, yellow, brown or red. The white varieties are the most palatable, while the darker varieties contain more tannin in the husk and protein availability and digestibility are reduced. For beer brewing the dark-colored grains are preferred.
2.2 Effect of Processing Methods on Nutritional Profile

Cereals and millets are the primary sources of minerals in most vegetarian diets, secondary sources being legumes. Besides inherent factors such as phytate, tannin, and fiber negatively influencing the bioavailability of zinc and iron from these food grains, the same may also be influenced by processing, such as cooking, boiling, roasting or germination which these food grains undergo. Food processing by heat generally alters the bioavailability of nutrients – both macro and micro. The digestibility and consequently absorption of micronutrients such as iron is believed to be improved upon heat processing by softening the food matrix, releasing of protein bound iron and thus facilitating its absorption. In addition, heat processing of food is also likely to alter the inherent factors that inhibit mineral absorption, such as phytate and dietary fiber, especially the insoluble fraction (Amparo et al., 2003).

Soaking, boiling and germination resulted in a significant reduction of phytate phosphorus. The concentrations of calcium, magnesium, iron and zinc increased upon soaking and germination, while boiling decreased calcium, magnesium and iron concentration. Solubility of minerals was higher in soaking and germination than in boiling (Sushma et al., 2008).

Despite an impressive array of nutrients in sorghum grain, sorghum-based foods have continued to be nutritionally deficient and organoleptically inferior. This is largely due to the presence of anti-nutritional factors (ANF) such as tannin, phytic acid, polyphenol and trypsin inhibitors which bind these food ingredients into complexes making them unavailable for human nutrition (Elsheik et al., 2000; Makokha et al., 2002; Mbofung and Fombang, 2003; Gassem and Osman, 2003; Gilani et al., 2005; Idris et al., 2007).

The presence of anti-nutritional factors limits the digestibility of proteins and carbohydrates by inhibiting their respective proteolytic and amylolytic enzymes (Yagoub, 2003; Mohammed et al., 2011).

They equally determine the bioavailability of divalent mineral elements which play key roles as enzyme stabilizers, transport co-factors in metabolic pathways and other key physiological functions. Specifically, sorghum tannins which are condensed polymeric polyphenols (proanthocyanidins) are capable of binding non-haeme iron
(Fe) and form complexes with proteins (Emmanbux and Taylor, 2003; Melaku et al., 2005), to inhibit enzymes of the digestive system (Ogunkoya et al., 2006).

Similarly, phytic acid (myoinositol hexaphosphate), present in most plant materials as phytate salt, is the main phosphorus store in mature seeds. Its association with proteins chelates metal ions (Alemu, 2009) to form protein-mineral-phytate complexes which are highly insoluble at the physiological pH of human intestine (Sandberg and Andlid, 2002).

Several methods have been generally adopted to improve the nutritional and organoleptic qualities of cereal-based foods. These include: genetic modification, amino-acid fortification, supplementation or complementation with protein- rich sources and processing techniques which include malting, milling and fermentation (Ugwu and Oranye, 2006; Mohammed et al., 2011).

Malting has been identified as the most inexpensive traditional processing technique for the elimination of the nutritional impediments of sorghum-based foods. Malting is a biotechnological technique which involves the controlled germination of a cereal grain which aims at activating enzyme systems that catalyze the hydrolysis of polymerized reserved food materials, notably, proteins, starches and cell-wall substances, thus, extracting fermentable materials (Ogbonna, 2011).

Four grist samples, the same sorghum variety, from a modulated malting condition, were evaluated for nutritional and anti-nutritional factors. A raw grist sample of the same sorghum variety served as control. Results showed mineral elements increasing significantly (p≤0.05) with increasing steeping and germination periods as follows: Na+ (123%), K+ (29.55%), P2+ (4.71%), Ca2+ (157%) and Mg2+ (93.33%). Proximate composition of the samples in relation to the control showed that the total ash and carbohydrate levels decreased significantly (p≤0.05) by 34.4% and 24.33% respectively. The crude protein also decreased significantly (p≤0.05) by 28.5% and later increased by 0.10% relatively to the control. The moisture content and crude fibre steadily increased significantly (p≤0.05) by 37.13% and 72.5% respectively. A highly significant (p≤0.05) increase of 111.82% in the crude fat of the malted samples over the control was observed. Conversely, the oxalate, tannin, trypsin inhibitor activity (TIA) and phytate levels were significantly (p≤0.05) reduced
by 34.13%, 8.45%, 36.5%, and 66%, respectively with increasing steeping and germination periods. The results suggest that malting, as a processing technique, can be used to effectively enhance the nutritional/organoleptic status of sorghum grist with concomitant reduction in some of its anti-nutritional factors. (Ogbonna, 2012)

Roasting is one of the processing steps to improve the flavor, characteristic of the whole-kernel is affected by the roasting condition to some extent. During roasting, the moisture content of most grain is reduced and the texture becomes more crumble and fragile (less hard). The roasting condition of whole-kernels should be properly controlled because it does not only contribute to development of flavor and aroma but also to the color of the product. Color is an important quality indicator of the roasting process. Development of roasted flavor and aroma depends upon the temperature and time of roasting besides the type of grains and techniques applied. A variety of foods, including those for infants are made from grains using traditional processing techniques such as roasting and malting.

Roasting and grinding processes render the grain digestible, without the loss of nutritious components. The puffing and roasting are almost similar processes, but the volume expansion in puffing is higher. Roasting of cereals, pulses and oilseeds is a simpler and more commonly used household and village level technology which is reported to remove most anti-nutritional or toxic effects such as trypsin inhibitor, hemagglutinin, gioterogenic agents, cyanogenic glycosides, alkaloids and saponins and increase storage life (Thapaliyal and Singh, 2015).

Traditional roasting of grains is used primarily for reduction of anti-nutritional factors and extension of storage life. Roasting produces pasty product with increased viscosity over other processing methods (fermentation and germination). Increase in viscosity contributed to the differences in percent moisture content of the component flours.

Germination of legume seeds is one of the processing methods to increase nutritive value and health promoting qualities. By this simple and inexpensive method different seeds have been germinated for human consumption. These include legumes like (soybean, lentils, and beans), cereals (rye, wheat, barley and oats) and seeds of some vegetables. Germination has been suggested as an effective treatment to remove
anti-nutritional factors from legumes and mobilizing secondary metabolites (Kaur et al., 2015). Therefore germination is cheap and more effective in improving nutritional value, it is hoped that this can contribute to nutrition of infants.

Germination is a natural process occurred during growth period of seeds in which they meet the minimum condition for growth and development (Hooda and Jood, 2003). It is a food processing method by which the quality of a cereal and legume can be improved for both digestibility and physiological function. During germination, enzymatic activity and bioactive compounds increased within the seed. It is induced by rehydration of the seed, which increases both respiration and metabolic activity that allow the mobilization of primary and secondary metabolites (Hassan et al., 2006).

For better utilization of millets, two processing techniques, viz., popping and malting were standardized using two local varieties of foxtail millet (Setaria italica). In popped samples, crude fat and crude fibre contents were significantly lower than raw millet in both the yellow and purple varieties, while the carbohydrate and energy values were significantly higher. In malted samples, crude protein and fat contents were significantly lower than in raw millet in both the varieties, whereas the carbohydrate contents were higher. Starch digestibility was highest (42.4%) in yellow popped samples and lowest in yellow malted samples (21.8%). Protein digestibility was highest (13.2%) in purple popped and lowest (2.4%) in yellow malted samples. (Choudhary et al., 2011)

Puffing or popping of cereals is an old practice of cooking grains since time immemorial to be used as snack or breakfast cereal like corn, either plain or with some spices/salt/sweeteners. Popping of sorghum is a cost effective process to obtain flour with improved starch characteristics and represents an unexploited opportunity to design novel and healthier cereal-based food products (Ushakumari et al., 2007). Popping improves the nutritional value by inactivating some of the anti-nutritional factors and thereby enhancing the protein and carbohydrate digestibility (Nirmala et al., 2000); it also enhances the appearance, color, taste and aroma of the processed raw material. Phytic acid content had a reduction of 20%-25% after popping. Popping helped to control phytic acid content in sorghum and enhanced protein as well as starch digestibility.
Nirmala et al. (2000) reported that in the germination process, both starch and protein are partially degraded, important for better digestibility and some of the flatus factors are also degraded. There is also overall improvement in the flavor profile.

Malting of finger millet improves digestibility and bioavailability of nutrients, improves sensory and nutritional quality. The significant increase in vitamin C content after malting is attributed to the enzymatic hydrolysis of starch by amylases and diastases, which degrade starch and produce glucose. This increased amount of glucose becomes the precursor of vitamin C. It is reported that during malting process calcium and phosphorus content increases whereas iron content decreases (Sangita and Sarita, 2000).

Improving the nutrient quality of sorghum seed by germination can help in reducing starch component, inducing hydrolytic enzymes synthesis such as phytate and reduction of some flavonoid components. Hence, germination of sorghum is very important in preparing for the development of food with low viscosity and high energy (Dicko et al., 2006).

Germination is a valuable process in reducing the viscosity of infants’ gruel and increases the total solid of such gruel and thereby increases the nutrients density of foods. (Ikujenlola, 2008)

Pawar et al. (2007) reported that malting of finger millet improves its digestibility, sensory and nutritional quality as well as pronounced effect in the lowering the anti-nutrients.

There are various benefits of malting such as vitamin-C is elaborated, phosphorus availability is increased and lysine and tryptophan are synthesized (Desai et al., 2010).

Narsih et al. (2012) revealed that the time of soaking and germination improves the nutritional value of sorghum. Soaking for 24 and germination for 36 h produced sorghum with higher nutritional values having characteristics such as protein digestibility (85.18%), non-protein nitrogen (0.28%), protein content (8.03%), fat content (1.64%), fiber (1.45%) and ash (2.24%).
Effect of popping on carbohydrate, protein, phytic acid and minerals of three varieties (pop sorghum, maldandi and red sorghum) of sorghum were studied by Saravanabavan et al. (2013). Significant changes (p≤0.05) in the starch degradability including total and soluble amylose content, and resistant starch occurred due to popping; in-vitro protein digestibility along with the content of albumin proteins increased. Starch characteristics had substantial differences among these three varieties which are based on the nature of endosperm and amylose content.

In a study on improving sorghum protein conducted by Dewar (2003), it was found that malting significantly (p < 0.05) improved the in vitro digestibility and the quality of sorghum protein by a staggering 110% increase in percentage protein, the nitrogen solubility index and lysine content by as much as approximately 8.5, 251 and 32%, respectively. The improvement in lysine content is not simply a consequence of protein concentration but rather a true increase in lysine.

2.3 Complementary feeding and foods

Complementary feeding is extremely essential from six months of age, while continuing breastfeeding, to meet the growing needs of the growing infant. The infant needs complementary feeding starting from 4-6 months. Many brands of preparatory foods have been developed and marketed; however these brands are too expensive and therefore are beyond the economics of low income families. The high price of proprietary complementary food and animal proteins combined with faulty feeding practices are mostly responsible for aggravating malnutrition among children.

Complementary feeding, i.e. introduction of foods other than milk to an infant's diet, is a major step in the development of food behavior, it represents a critical stage from both nutritional and behavioural standpoints, likely to affect the infant's growth and health (Greer et al., 2008; Sloan et al., 2008; Zutavern et al., 2008 and Morgan et al., 2004).

Complementary foods, introduced to children between the ages of 6 months to 3 years, are liquids and semisolids, which are later replaced by solid foods. In addition to providing adequate nutrition, weaning foods should possess proper functional properties. According to WHO (2003), good quality weaning food must have high nutrient density, low bulk density, low viscosity and appropriate texture along with
high energy, protein and micronutrient contents and have a consistency that allows easy consumption.

Complementary feeding period means the period when older infants (above six months) and young children transition from exclusive feeding of breastmilk and/or breastmilk substitutes to eating the family diet. It is the process of giving a child other food while continuing breastfeeding, when her or his nutritional demands can no longer be fulfilled by breastfeeding alone. Appropriate complementary feeding should be timely, culturally acceptable, nutritionally adequate, safe and responsive. It is the time when malnutrition starts in many infants, contributing significantly to the high prevalence of malnutrition in children less than 5 years of age worldwide (Daelmans & Saadeh, 2003).

Guidelines for weaning foods suggest that weaning can occur between the ages of 6-12 months. The foods given should have characteristics according to nutritional needs, appropriate textures and viscosity, and appropriate forms (liquid, semisolid, solid) to support mental and physical development.

Protein energy malnutrition (PEM) generally occurs during the crucial transitional phase when children are weaned from liquid to semi solid or fully adult foods. Children therefore require nutritionally balanced calorie-dense supplementary foods in addition to mother’s milk. Processed-cereal based complementary food, commonly called as weaning food or supplementary food means foods based on cereals and/or legumes (pulses), soyabean, millets, nuts and edible oilseeds, processed to low moisture content and so fragmented as to permit dilution with water, milk or other suitable medium. Processed-cereal based complementary foods are obtained from variety of cereals, pulses, soyabean, millets, nuts and edible oilseeds after processing. (Guidelines For Enhancing Optimal Infant And Young Child Feeding Practices, Govt. of India, 2013).

 Appropriately thick complementary foods of homogenous consistency made from locally available foods should be introduced at six completed months to all babies while continuing breastfeeding along with it. This should be the standard and universal practice. During this period, breastfeeding should be actively supported and
therefore the term “weaning” should be avoided (National Guidelines on Infant and Young Child Feeding, 2004).

To address the issue of a small stomach size which can accommodate limited quantity at a time, each meal must be made energy dense by adding sugar/jaggery and ghee/butter/oil. To provide more calories from smaller volumes, food must be thick in consistency -thick enough to stay on the spoon without running off, when the spoon is tilted. Foods can be enriched by making a fermented porridge, use of germinated or sprouted flour and toasting of grains before grinding (National Guidelines on Infant and Young Child Feeding, 2010).

Weaning food based on malted millet flour, roasted soybean flour and skim milk powder was developed by Thathola and Srivastava (2002). Their mix contained 18.37g protein and 398 kcal energy per 100g. The protein efficiency ratio of the mix was 2.25 against a casein control, for which a value of 2.50 was recorded. They found that the nutrient composition, viscosity and sensory quality of the weaning mix were comparable with the marketed weaning mix (commercial infant formula).

Strategies to improve the availability and accessibility to low cost fortified complementary foods can play an important role in behavioral changes necessary to improve the nutritional status of infants and young children (Rivera and Lutter, 2001).

Developing nutrient dense, fully cooked, ready to eat inexpensive supplementary foods from the locally grown food ingredients has been strongly recommended as a viable and sustainable approach to address the problem of under nutrition in developing countries (WHO, 2000; Dewey and Brown, 2003).

Asma et al. (2006) prepared weaning blends which composed of 42% sorghum supplemented with 20% legumes, 10% oil seeds, and 28% additives (sugar, oil, skim milk powder, and vanillin). The blends were found to contain 16.6% to 19.3% protein, 68.7% to 72.7% carbohydrate, 0.9% to 1.3% fiber, and 405.8 to 413.2 kcal of energy per 100 g. The iron content of the blends ranged from 5.3 to 9.1 mg/100 g, and the calcium content ranged from 150 to 220 mg/100 g. All blends reconstituted well and formed a soft paste when stirred with hot or cold water. Sensory attributes, viscosity values, and in vitro digestibility varied among the blends, whereas lysine content improved considerably (p ≤ 0.05) for all blends. All blends
had similar keeping quality, with no signs of spoilage or development of off-flavors or colors after 10 months of storage. Most blends remained free of aflatoxins. It was concluded that legumes and oil seeds can be effectively used in sorghum-based weaning foods as an acceptable protein and mineral supplement.

Lalude and Fashakin (2006), conducted a study on use of locally sourced flours of germinated sorghum, sesame oil seed, groundnut and soybeans which were combined in the ratio of 3 ½ : 1:1:1 (w/w), to produce weaning diet rich in energy and protein. The results showed significant differences (p<0.05) between the experimental diet and a commercial weaning diet - “Nutrend” (Nestle, Nigeria) in terms of protein content, minerals and energy content. The experimental diet showed higher values when compared with the commercial diet. Also, the physico-chemical characteristics of the experimental diet were improved upon in terms of bulk - density, swelling capacity, viscosity and water - holding capacity. The animal feeding experiment further showed higher values of PER (Protein Efficiency Ratio), FER (Food Efficiency Ratio) and Total Tissue Nitrogen for the experimental diet.

In a study by Satter et al. (2013), there was an attempt to develop nutritionally enriched instant weaning food and evaluate its safety aspects. The developed instant weaning food contained the major nutrients like moisture, ash, fat, protein, fiber, carbohydrate and energy 2.43%, 2.26%, 11.32%, 15.98%, 1.06%, 75.35% and 456.6 kcal/ 100 g, respectively and was comparable to three good quality imported commercial weaning foods in Bangladesh.

Parvin et al. (2014) carried out a study to develop and evaluate a cereal based highly nutritive supplementary food for young children. The formulated baby food had low ash contents (1.88g/100g), 0.58% crude fiber, 11.91 g/100g protein, 8.61g fat, 74.39g/100g carbohydrates and provided 433.9 kcal of energy per 100g on dry weight basis. The formulated baby food was found nutritionally rich and safe in microbial point of view comparable to imported baby foods.

In a study by Wakil and Onilude (2009), the available calcium ranged from 135.28 mg/kg to 419.67 mg/kg while available iron ranged from 16.31 mg/kg to 52.90 mg/kg, a high amount of available magnesium (885.05 mg/kg) was found in malted and fermented cereal-legume weaning foods.
Percentage *in-vitro* protein digestibility of the formulations ranged from 75 to 82% in the complementary foods formulated using malted maize, millet and sorghum with groundnut and soyabeans. (Anigo *et al.*, 2010)

Legumes are known to contain lysine in a quantity that exceeds the requirements for human but with the low content of sulphur amino acids. Legumes have been considered as a major source of protein supply to the people of world. They contain two to three times more protein than cereals. Plant proteins are alternative to proteins from animal sources for human nutrition and so the legumes are recognized as the best source of vegetable protein (Molina *et al.*, 2002).

Cereals, on the other hand, are high in the sulphur amino acids but deficient in lysine. A mutual complementation of amino acids and consequent improvement in protein quality is therefore achieved when legumes are blended with cereals in the right proportions (Ghasemzadeh and Ghavidel, 2011).

Mung bean or green gram (*Vigna radiata*), also called green gram is a tropical legume, widely grown in Asia, particularly in Thailand, India and Pakistan. Green gram is third most important crop of India, in terms of cultivated area and production, accounting for nine per cent of total legumes production (Singh and Ahlawat, 2005).

Green gram is rich source of protein and amino acid especially lysine and thus can supplement cereal based human diets. It is good source of thiamin, niacin, vitamin B6, pantothenic acid, iron, calcium, magnesium, phosphorus and potassium and very good source of dietary fiber, vitamin C, vitamin K, riboflavin, folate, copper and manganese. Green gram is a potential source of essential fatty acids and antioxidants. (Rana, 2015)

Chickpea (*Cicer arietinum*) is widely consumed throughout the world. Chickpea seeds are rich source of protein ranging from 12.6 to 30.5%. The biological value of chickpea proteins generally ranges from 75 to 85%, which is considerably higher than other legume and cereal proteins. Functional properties, which are assuming greater significance in terms of diversified and novel food uses of crops, play an important role in the utilization of chickpea in the cereal- based composite flours. Processing techniques such as germination and fermentation have been found to improve the quality of cereals and legumes due to chemical changes that enhance
contents of free sugars, protein and vitamins, as well as bioavailability of minerals (Helland et al., 2002; Ochanda et al., 2010), and results in the breakdown of some of the anti-nutritional endogenous compounds (Ahmed et al., 2006).

Chickpea is the primary pulse crop in South Asia where it is an important source of protein particularly in vegetarian diet. India has highest area, production and consumption of chickpea in the world. Chickpea is a good source of protein and carbohydrates, possessing vitamins like thiamine, niacin, minerals like Ca, P, Fe, Mg and K and unsaturated fatty acids such as oleic acid and linoleic acid (Moreno et al., 2004).

There are two main commercially available types of chickpea grown in the world: the desi and the kabuli chickpea. Desi chickpea seed is small with a dark irregular-shaped seed coat and is grown on semi-arid land. Kabuli chickpea (Garbanzo beans) is larger than desi chickpea, has a thin light-colored seed coat and is normally grown in temperate regions of the world. A variety of desi and kabuli chickpeas have been developed and the characteristics of these cultivars may vary depending on the producing region (Agriculture and Agri-Food Canada, 2008).

Usha et. al. (2010) developed a cereal-pulse complementary food fortified with different concentrations of pumpkin powder (Cucurbita moschata), and analysed its sensory and physico-chemical parameters. Sorghum (Sorghum vulgare) and whole green gram (Vigna radiate) were germinated, dried, pulverised and combined with powdered rice (Oryza sativa) in the ratio of 2:1:1. Pumpkin powder was added to this mixture at 10%, 20% and 30% variations. Nutritional analysis of the weaning mix demonstrated that there was a significant increase in the protein, fibre, carbohydrate and antioxidant levels with an increase in concentration of pumpkin powder. The sensory analysis revealed that the complementary food mix with 20% pumpkin powder fortification had good sensory qualities.

Normah and Jirapa (2000) conducted a study with the to identify the effect of different drying methods on vitamin A activity of formulated weaning food, formulated using treated cowpea flour, locally available rice flour, banana-pumpkin, skim milk powder and sugar in the ratio 35:35:15:15:5. The carotenoid composition of the product was determined by HPLC. Vitamin A activity of oven-dried weaning
food was significantly reduced (p<0.05) compared to freeze-dried weaning food. The freeze-dried weaning foods showed a higher retinol equivalent than oven-dried weaning foods for all treatments. The results of the study found that an intake of 100 g of freeze-dried weaning foods enriched with banana-pumpkin and cowpea flour provided an adequate amount of the recommended daily allowance (RDA) of vitamin A for infants.

In a study titled development of a low cost energy dense complementary food for poor society’s young baby in Bangladesh by Obidul et al. (2013), three types of complementary foods were formulated by certain proportion mixing of cereals (boiled rice, kalozira rice), legumes (bengal gram, black Gram, mung bean), sugar, milk powder and vegetables (carrot and pumpkin) in powdered form after proper processing of all ingredients. The recipe was standardized and analyzed and the nutritive values of the final complementary food contain 15.5% protein, 13.7% fat, 56.3% carbohydrate, 2.62% ash and energy 415 kcal per 100g. On the other hand, equal amount of locally available market foods contain similar amount of nutrients although it was high prices. Comparing the various sample and market results, it was found that the standardized sample was comparatively suitable for use as complementary food at convenient prices.

Adepeju et al. (2014), in his study, recorded the amount of mineral content of the complementary diets prepared from breadfruit, soybean and groundnut, to be ranging between 1.1 to 2.5mg/100g for iron; 43.85 to 68.4mg/100g for calcium; 20.69 to 49.07 mg/100g for magnesium and 0.49 to 0.64 mg/100g for zinc.

Nicole et al. (2010) studied the characterization of ready-to-eat composite porridge flours made by soy-maize-sorghum-wheat extrusion cooking process. Two composite flours were formulated sorghum-maize-soy I (SMS1) and sorghum-maize-soy II (SMS2). SMS II had higher content (p<0.05) of zinc, magnesium and phosphorus than SMS I. SMS I and SMS II had protein content of 23.87 and 17.95 per cent weight respectively with energy value of 1694.89 and 1540.88 Kilo Joule/100g, respectively while in-vitro protein digestibility was found at 72.32 and 68.85 per cent weight, respectively.
2.4 Physico-chemical Properties

Physico-chemical property of a food is important because it indicates the utility of products in specific applications and therefore reflects the properties encountered by their use during the preparation of usable products; reduce processing losses and helps in improving the overall quality of the product. These denote characteristics that govern behavior of foods during processing, storage and preparation as they affect food quality and consumer acceptability (Sangwan, 2002).

Functional properties (solubility, foamability, gelation and emulsification properties) are the intrinsic physicochemical characteristics which may affect the behaviour of food systems during processing and storage. Adequate knowledge of these physicochemical properties indicates the usefulness and acceptability for industrial and consumption purpose. (Ogunbemile et al., 2002)

High bulk density limits the caloric and nutrient intake per feed of a child which can result in growth faltering. In contrast, however, low bulk density would be an advantage in the formulation of complementary foods (Ugwu and Ukpabi, 2002).

Viscosity is an important functional property of foods that affects mouth-feel and textural quality of fluid food which has shown that viscosity is a function of not only the solid concentration, but also the type of starch and protein the product bears.

Weaning foods are often fed to infants as semi-solid gruels. Viscosity and energy density of weaning foods are important issues to assure appropriate energy intake for the infant. The required energy density of weaning foods depends on the age of the child, the feeding frequency and the amount of human milk consumed. Cereal based weaning foods have high contents of starch, resulting in high viscosity. In developing countries, weaning foods are often based on foods prepared for adults, i.e. thick cereal and/or legume gruels, diluted with water to reduce the viscosity, resulting in low energy and nutrient density, the most efficient way to reduce viscosity, without decreasing energy and nutrient density, was found to be by the addition of the starch degrading enzyme amylase. Amylase rich flours (‘power flour’) can be prepared at the household level by germinating local cereal grains, such as millet, maize or sorghum, which are subsequently dried, milled and added to the weaning foods (Gopaldas and Deshapande, 1992).
Ozumba et al. (2002) reported that the flour prepared from sprouted grain can be used in greater amount to give the same viscosity as flour from ungerminated grain, thereby obtaining more nutrients and energy.

The water-holding capacity, wettability, and bulk density were within the ranges of corresponding values of commercial weaning foods (Asma et al., 2006).

In a study done by Elkhalifa and Bernhardt (2010) on functional properties of sorghum flour it was concluded that, the flour prepared from germinated grains can be used in greater amount to give the same viscosity as flour from germinated grain, thereby obtaining more nutrients and energy.

The water absorption capacity of formulated weaning foods were significantly ($p \leq 0.05$) lower than the levels in commercial weaning food. The high fat, high protein, low carbohydrate content of weaning food corresponds to the reduced water absorption capacity observed (Griffith et al., 1998). When starch content is high as in commercial weaning food then the water binding capacity also high because starch absorbs more water. Lower absorption capacity is desirable for making thinner gruels (Ghasemzadeh and Ghavidel, 2011).

The spreadability and viscosity are of great significance (Subba Rao et al., 2004) with respect to feeding of weaning food reduced viscosity would enable the child to take more volume of product per feed and total nutrient intake would be high, which is great benefit of the product developed.

Ikujenlola and Adurotoye (2014) evaluated the quality characteristics of high nutrient dense complementary food from mixtures of malted quality protein maize (Zea mays L.) and steamed cowpea (Vigna unguiculata). The water absorption capacity, bulk density, peak and final viscosities were significantly ($p>0.05$) reduced in the malted samples. The products resulting from this study were of high protein, good mineral content and low bulk density, low water absorption and low viscosity.

3.5 Shelf-life Assessment

Shelf-life is the length of time that a commodity such as food may be stored without becoming unfit for use or consumption. It is the recommended maximum time for which products can be stored during which the defined quality of a specified
proportion of the goods remain acceptable under expected conditions of distribution, storage and display (Ibeanu et al., 2015).

A food product within its shelf life should be safe to eat, keep its appearance, colour, texture and flavour and meet any nutritional claims provided on the label. All foods spoil with time but the rate differs from food to food. Factors that affect food quality include microbial (bacteria, yeast and mold) growth, non-microbial spoilage (rancidity, browning and loss of nutrients) and product related spoilage such as water activity, pH and oxygen availability (Fontana, 2008; Sivasankar, 2010).

Microbial load of a food is determined by the levels of microorganisms (measured in colony forming units per gram) in the food during production, packaging, storage and other handing as well as the type of food in question. The end of shelf life can be based on the quantity of microorganism present (Ibeanu et al., 2015).

Free fatty acid in stored foods is used to measure rancidity. Enzymes inherent in foods hydrolyze fat in the food into free fatty acid and glycerol during storage (Morrison, 2006). Light, atmospheric oxygen and moisture also precipitate rancidity which changes the flavour and taste of food (Modi et al., 2004).

According to Vincent (2002) materials such as flour and starch containing more than 12% moisture have less storage stability than those with lower moisture content which will allow low growth of bacteria and fungi. High moisture content thus predisposes such food to degradation and enhances perishability.

The percent moisture content recommended for weaning food is in the range of 5-10% (Olorunfemi et al., 2006). Amankwah et al., (2009) reported that the removal of moisture generally increases concentration of nutrients and can make some nutrients more available. Low moisture content of flours prevents microbial activity and extends the shelf life of the flour (Kikafunda et al., 2006; Adebayo-Oyetoro et al., 2011).

In a study by Pampangouda et al. (2015) there was a slight change in protein content during storage for 90 days which was not significant between the treatments, hence the changes did not influence the quality and shelf-life of flour up to three
months in all the samples. Similar results were reported by Chandru, et al., (2010) where protein content was slightly decreased in finger millet flour up to six month storage.

To analyze the effect of packaging and storage condition on functional properties and quality attributes cassava flour, it was observed that the effect of exposure to heat during flour processing acted as a catalyst for oxidation which leads to carotenoid degradation (Uchechukwu-Agua, 2015). Another investigation by Oliveira et al. (2010) and Chukwu and Abdallah (2015) agree with the carotenoid reduction trend observed from this study and therefore justify that carotenoid retention is a function of the length of storage such that the longer the storage period the higher the percentage loss.

Decrease in mineral content was observed in sun-dried okra seeds in 20 weeks of storage period. The seeds showed an initial increase in calcium content upto 12 weeks and after 16th week, the content started decreasing. (Fagbohun and Faleye, 2012)

The infant foods were prepared by using rice, wheat or corn and concentrated soymilk and fortified with vitamins and minerals. Rate of water absorption during at room temperature was insignificant and, after 6 months of storage, a negligible increase in peroxide value was detected, indicating that the products remained acceptable. Total bacterial counts were $8 \times 10^1$, $8.2 \times 10^1$ and $10.5 \times 10^1$ for rice, corn and wheat-based products, respectively. Fungi, coliforms, Salmonella and Shigella were absent in all foods (Wadud et al., 2004).

Ahmed et al., (2008) observed no remarkable change in moisture content, PV, FFA and flavour upto four months of storage of weaning food (Soya bean based). However, after 4 months, a greater increase in PV and FFA values were noticed with rancid flavor.

Asma et al. (2006) developed sorghum based staple dried flakes as instant weaning foods composed of 42% sorghum supplemented with 20% legumes, 10% oil seeds, and 28% additives (sugar, oil, skim milk powder, and vanillin) were prepared and processed in a twin-roller drum dryer. The total bacterial counts of the blends ranged from $7.2 \times 10^2$ to $7.6 \times 10^4$ cfu/g, even after storage of the blends for 10 months
at 4°C or 25°C. The results indicated that the blends were stable against microbial attack. All blends had similar keeping quality, with no signs of spoilage or development of off-flavors or colors after 10 months of storage. Most blends remained free of aflatoxins.

Development and evaluation of composite flour for *missi roti / chapati* was carried out by Kadam et al. (2012). Four types of blends in different ratio viz; ‘A’ wheat flour: chickpea flour (80:20). ‘B’ wheat flour: fullfat soy flour (90:10) ‘C’ wheat flour: chickpea flour: soy flour (80:10:10) and ‘D’ wheat flour: chickpea flour: soy flour: *methi* leaves powder (75: 10: 10: 05). They contained proteins (11.8 to 15.37%), fat (1.53 to 3.45%), fibre (1.24 to 2.05%), ash (2.08 to 2.70%) and carbohydrates (65.99 to 74.2%). All these blended flours were found to have good sensory quality characteristics of products as control. All these blended flours could be well stored in polyethylene bags or tin boxes for the period of 3 months without any deterioration of quality.

Balasubramanian et al. (2014) developed upma mix which was monitored for peroxide value, free fatty acids and thiobarbituric acid value as well as sensory quality during storage and was found stable for 6 months at ambient conditions (20–35 °C) in poly ethylene pouches (75 μ).

A ready to serve instant halwa powder was developed by Devraj et al. (2007), with potato flour (39.6g), ghee (9.9g), sugar powder (43.6g), cardamom, fennel, coconut and cashew nut as condiments. They reported that the product remained stable when packed in polyethylene bags and stored for 6 months at room temperature.

In a study by Mamta (2015) on pearl millet based convenience foods, a significant increase in peroxide value was observed in the three types of idli, dhokla and upma mixes prepared, but, all types of mixes were in the permissible limits of palatability.

Itagi et al. (2013) prepared multigrain halwa mixes (four types) from cereals, millets, legumes, nuts and condiments. These mixes had around 4% initial moisture content (IMC), during storage studies they had 23 to 32% as equilibrium relative humidity; 5 to 8% as the critical moisture content and critical relative humidity for
these mixes were ~60%. Packaging material for storing these mixes was 75 μm thickness LDPE pouches. Under accelerated storage, these mixes picked up moisture up to 9% and at ambient temperature up to 6.4%. Free fatty acids increased by 18% under accelerated condition after 90 days; under ambient condition ~14% for 180 days. Pearl millet based halwa mix had FFA increase up to 120%, which was due to the presence of tricarboxylic acid as one of the ingredient in this particular mix. Halwa mixes could be stored for 75 days under accelerated and 180 days under ambient conditions.

Singh et al. (2013) prepared instant multigrain dalia mix based on sorghum, pearl millet and maize. Physicochemical changes in the dalia mix stored at 10, 25, 37 and 45°C for 180 days were monitored. Hydroxy methyl furfural, free fatty acids and thiobarbituric acid value for the product increased significantly with increase in temperature and progression of storage period. The potential shelf life of instant multigrain dalia mix was 71 weeks at 10°C.

Instant mixes prepared from pearl millet with bengal gram made it to the category of ‘liked slightly’ by the judges in respect to colour, appearance, texture on 60th day of storage whereas the mean scores of aroma and taste were ‘neither like nor dislike’ as reported by Rathi et al.(2004).

Kumari (2002) studied porridge prepared from 0, 30 and 60 days of stored instant mixes fell in ‘liked moderately’ to ‘liked very much’ categories in terms of all the sensory characteristics of nine-point Hedonic Scale.

Hooda and Jood (2005) reported that control and supplemented biscuits can be stored safely in polyethylene bags at room temperature for 30 days without any adverse changes in the organoleptic traits.

Mridula et al. (2009) prepared bengal gram sattu and stored it for 180 days. Sensory characteristics scores of fresh sample showed that overall acceptability was 8.12 and after storage it was decreased to 8.04. Similarly, Mridula et al. (2010) also reported that bengal gram sattu could be stored for up to six months without affecting sensory characteristics.
The microbial population of instant dhokla mix developed using soybean, ragi and garden-cress seeds was evaluated and initially low population was observed which increased on 180\textsuperscript{th} day of storage up to 5x10\textsuperscript{2} cfu/gm. (Lohekar and Arya, 2014)

The bacterial count of the fresh, 30 days and 60 days old 20 percent potato flour incorporated biscuits sample after 60 days was 3x10\textsuperscript{3} cfu/g, 4.5x10\textsuperscript{3} cfu/g and 6.5x10\textsuperscript{3} cfu/g, respectively and this was well below the acceptable limit and there was no rancidity development observed in the formulated biscuits up to 60 days. (Seevaratnam \textit{et al.}, 2012)

In a study on nutritional evaluation of value-added products using wheat-sorghum-soybean flour blends (Pandey, 2015), the total bacterial count was within the permissible limit up to 45 days. The increase in total bacterial count might be due to the availability of moisture, carbohydrate and protein content in developed products, which serve as a suitable media for growth of bacteria.

Kumari (2002) studied porridge prepared from 0, 30 and 60 days of stored instant mixes fell in “liked moderately” to “liked very much” categories in terms of all the sensory characteristics of nine-point Hedonic Scale.

Hooda (2002) concluded that supplemented biscuits and control biscuits could be stored safely in polythene bags without any adverse changes in the organoleptic traits upto 60 days at room temperature. Similarly, Srivastava \textit{et al.}, (2003) reported that foxtail millet biscuits and control (refined wheat flour) could be stored well in thermally sealed polythene bags at room temperature (32-37\textdegree C) for 60 days.